OFF-OIL ENERGY GENERATION AND CONSERVATION OPPORTUNITIES FOR REMOTE COMMUNITIES

with particular reference to Hartley Bay, B.C.

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Prepared for:

Hartley Bay Indian Band
and
Indian and Northern Affairs Canada

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CONTENTS

		Page
1.0	EXECUTIVE SUMMARY	1
	RESUME	3
2.0	BACKGROUND	
2.1	INTRODUCTION AND OBJECTIVES	5
2.2	ENERGY CONSIDERATIONS IN REMOTE COMMUNITIES	9
2.3	HARTLEY BAY COMMUNITY	10
3.0	ENERGY INVENTORY AND ANALYSIS	
3.1	INTRODUCTION AND METHODOLOGY	12
3.2	ENERGY DEMAND ANALYSIS	17
	3.2.1 General	17
	3.2.2 Residential Demand	18
	3.2.3 Non-Residential Demand	22
	3.2.4 Energy Supply and Conversion	24
	3.2.5 Energy Projections	25
3.3	HARTLEY BAY INVENTORY	27
	3.3.1 Electrical Generation System	27
	3.3.2 Village Energy Supplies	28
	3.3.3 Buildings Survey and Projections	30
	3.3.4 Appliance Inventory	36
3.4	HARTLEY BAY ANALYSIS	37
	3.4.1 General	37
	3.4.2 Energy Supply (Inputs) and Conversion	39
	3.4.3 Energy Consumption (End-Uses)	43
	3.4.4 Future Requirements	49
4.0	CONSERVATION OPTIONS	
4.1	INTRODUCTION	54
4.2	ENERGY MANAGEMENT	55
4.3	INSULATION	56
	4.3.1 General	56
	4.3.2 Hartley Bay	59
4.4	DIESEL WASTE HEAT RECOVERY	62
	4.4.1 General	62
	4.4.2 Hartley Bay	65
4.5	SITING	65
	4.5.1 General	65
	4.5.2 Hartley Bay	66
4.6	HEAT PUMPS	67
	4.6.1 General	67
	4.6.2 Hartley Bay	68

		Page
5.0	ALTERNATIVE ENERGY RESOURCE OPTIONS	
5.1	INTRODUCTION	69
5.2	HYDRO-ELECTRIC	69
	5.2.1 General	69
	5.2.2 Hartley Bay	70
5.3	WIND	72
	5.3.1 General	72
	5.3.2 Hartley Bay	73
5.4	WOOD	73
	5.4.1 General	73
	5.4.2 Hartley Bay	74
5.5	GEOTHERMAL	75
	5.5.1 General	75
	5.5.2 Hartley Bay	77
5.6	GASIFICATION	78
	5.6.1 General	78
	5.6.2 Hartley Bay	80
5.7	COAL	80
	5.7.1 General	80
	5.7.2 Hartley Bay	81
5.8	SOLAR	82
	5.8.1 General	82
	5.8.2 Hartley Bay	83
5.9	BIOGAS	83
	5.9.1 General	83
	5.9.2 Hartley Bay	84
5.10	NATURAL GAS AND PROPANE	84
	5.10.1 General	84
	5.10.2 Hartley Bay	85
5.11	GRID EXTENSION	86
	5.11.1 General	86
	5.11.2 Hartley Bay	87
6.0	EVALUATION OF ENERGY ECONOMICS	
6.1	GENERAL CONSIDERATIONS	89
6.2	POLICY CONSIDERATIONS	91
	6.2.1 Electrical Supply Policy	91
	6.2.2 Housing Policy	92
	6.2.3 Energy Pricing	93
6.3	COMPUTER MODELLING	95
7.0	EVALUATION OF SELECTED PROGRAMS AT HARTLEY BAY	
7.1	INTRODUCTION	101
7.2	ALTERNATIVE 1 - APPROPRIATE PRICING AND INCENTIVES	103
7.3	ALTERNATIVE 2 - INSULATION	104
7.4	ALTERNATIVE 3 - DIESEL WASTE HEAT RECOVERY	107

		Page
7.5	ALTERNATIVE 4 - HYDRO-ELECTRIC GENERATION	108
7.6	ENVIRONMENTAL AND SOCIOECONOMIC CONSIDERATIONS	114
	7.6.1 Environmental Impacts	114
	7.6.2 Socioeconomic Considerations	116
8.0	SUMMARY	
8.1	DATA COLLECTION AND HARTLEY BAY	119
8.2	SPACE HEATING AND ENERGY CONSERVATION	120
8.3	OTHER ENERGY SOURCES	121
8.4	CONSUMPTION PATTERN	121
8.5	COMPUTER PROGRAM	122
8.6	FINDINGS AT HARTLEY BAY	123
9.0	RECOMMENDATIONS	
9.1	REMOVE COMMUNITIES IN GENERAL	127
9.2	HARTLEY BAY	127
	APPENDICES	
A1	ALTERNATIVE ENERGY RESOURCE OPTIONS	129
A2	AVERAGE APPLIANCE ENERGY REQUIREMENT	156
A3	ENERGY AUDIT SURVEY FORM	157
B1	HARTLEY BAY DEMOGRAPHIC PROJECTIONS	158
B2	HARTLEY BAY ENERGY REQUIREMENTS - BASE CASE	159
B3	HARTLEY BAY ENERGY REQUIREMENTS - ALTERNATIVE 2	160
B4	HARTLEY BAY ENERGY REQUIREMENTS - PROJECTIONS	161
C	EXAMPLES OF ENERGY-EFFICIENT HOME PROGRAMS	166
	REFERENCES	167

LIST OF FIGURES

		Page
2-1	Remote Indian Reserve Locations in British Columbia	7
3-1	Hartley Bay Projected Energy Requirements	51
6-1	Observed Electrical Demand as a Function of Price	94
6-2	EDF Computer Program Flow Diagram	98

LIST OF TABLES

2-1	Remote Indian Reserves in British Columbia	8
3-1	Residential Heat Loss Values	20
3-2	Residential Energy Demand	23
3-3	Energy Conversion Efficiency Factors	26
3-4	Hartley Bay Energy Supply	31
3-5	Hartley Bay Inventory of Buildings	32
3-6	Hartley Bay Housing Insulation Inventory	35
3-7	Hartley Bay Residential Appliance Stock	38
3-8	Hartley Bay Estimated Total Electrical Production and Consumption	41
3-9	Hartley Bay Residential Electrical Consumption	42
3-10	Hartley Bay Energy Consumption Profile	47
3-11	Hartley Bay Residential Energy Analysis	48
4-1	Diesel Waste Heat Availability	64
7-1	Alternative 1 - Appropriate Pricing and Incentives	105
7-2	Alternative 2 - Insulation	106
7-3	Alternative 3 - Diesel Waste Heat Recovery	111
7-4	Alternative 4 - Hydro-Electric Generation	112
7-5	Oil Savings on Hydro-Electric Alternative	113

1.0 EXECUTIVE SUMMARY

The objective of this study has been to identify potential opportunities for energy conservation and alternative energy sources in remote communities. Such opportunities will depend on their individual circumstances.

In parallel with this effort, a relatively simple computer program has been established for the study. This program consists of three modules. The first estimates energy consumption and cost for each sector and end use. The second produces demographic projections of population and changes in housing stock, from which energy consumption trends for the community over an extended period of time are obtained. The third carries out standard economic projections for any proposed option. Comparison with the diesel generator base case provides measures of economic benefit payback period, and off-oil saving.

The remote community of Hartley Bay, British Columbia, with a village population of 234, which is expected to grow at between 1 and 1.5 per cent per annum, was selected as a case study. Findings of specific interest are briefly summarized as follows:

- Hartley Bay spends approximately $190,000 per annum on all forms of oil, equivalent to $800 per person.
- This represents 90 per cent of the total energy input to the village.
- Residential space heating accounts for 60 per cent of the total.
- There is a wide disparity in house construction, making it necessary to classify housing stock into four types for energy assessment purposes.
- The poorest group of houses will be replaced in two years under the present replacement policy of Indian Affairs.
- The next best group (designated Type A) could benefit significantly from the installation of some form of floor insulation.
- Based on comparable data from non-remote communities, it is estimated that for the range of existing appliances at Hartley Bay, electrical consumption per household should be about 540 kWh per month. DIAND allows 700 kWh. Actual consumption per household averages 990 kWh per month. Overall electricity consumption in the village is about 78 per cent higher than it should be.

- A substantial part of this excess must be attributed to unauthorized electric space heating. In turn, this unauthorized use is directly encouraged by the policy of a flat-rate monthly electricity charge.

- Conversely, the consumption level of heating oil is substantially lower than expected.

- In fact, gross energy consumption in the village is about 80 per cent of that of a comparable non-remote community.

- Since a substantial portion of the oil consumption is inappropriately converted through the diesel electric heater system, at a much lower overall efficiency than direct oil space heating, the net useful energy consumption is even lower, at about 70 per cent. In other words, the community energy lifestyle is about 70 per cent of a comparable non-remote community. This is the extent to which the demand may be considered to be "capped". Under uncapped conditions, demand may be expected to grow as much as 40 per cent more than the present net useful energy level.

- The small scale hydro scheme of approximately 500-600 kW firm power proposed for Hartley Bay would virtually eliminate the growing consumption of approximately 440,000 L of oil per annum. The scheme would attract outlying population back to the village, possibly encourage local industry, and pay for itself in 14 years.

- Other short term off-oil opportunities with good payback periods are suggested. However, none represent a complete solution, and higher overall energy consumption levels can be expected, rather than reduced use of oil.

The report concludes with the recommendation that before considering other opportunities at Hartley Bay, a policy decision should be taken on whether or not to pursue the hydro option.

The report also recommends that a program of data collection should be instituted at other remote communities to determine consumption patterns and to identify similar off-oil opportunities.

MODES D'UTILISATION ET ECONOMIES D'ENERGIE SURTOUT A HARTLEY BAY (C.-B.)

Résumé pour la direction

Cette étude visait à repérer d'éventuelles sources d'économie d'énergie et d'utilisation d'énergies de remplacement dans des collectivités éloignées. Ces possibilités varient selon la collectivité.

Parallèlement à ces travaux, un programme informatique relativement simple était mis à l'oeuvre. Il se compose de trois modules. Le premier sert à évaluer la consommation et le coût de l'énergie de chaque secteur et sa destination finale. Le deuxième établit des projections démographiques de la population et des variations de stocks d'habitation à partir desquelles sont prévues les tendances de la consommation d'énergie au sein de la collectivité pour une période prolongée. Le troisième, enfin, fait les projections économiques courantes de chaque scénario. Une comparaison avec le scénario de base reposant sur l'utilisation d'un groupe électrogène au diesel permet de mesurer la période de récupération de l'investissement et l'économie de pétrole.

Le village de Hartley Bay, d'une population de 234 qui devrait croître à un rythme de 1 à 1,5 pour cent par année, a été retenu pour étude de cas. Voici une brève description des conclusions d'intérêt particulier:

- Hartley Bay débourse au total environ 190 000$ par année à l'achat de pétrole sous toutes ses formes, ce qui revient à 800$ par personne.

- Ces achats représentent 90% de toute l'énergie consommée au village.

- Soixante pour cent de ce total sont consacrés au chauffage dans le secteur résidentiel.

- La construction des maisons est très variée, ce qui rend nécessaire une classification des constructions en quatre genres pour l'évaluation de l'énergie.

- Le groupe de maisons au pire rendement sera remplacé d'ici deux ans en vertu de la politique actuelle de remplacement du ministère des Affaires indiennes et du Nord du Canada (MAINC).

- Le groupe qui le précède (désigné de type A) pourrait bénéficier énormément de la pose d'un certain matériau isolant les planchers.

- D'après des données comparables relevées dans des collectivités plus rapprochées des grands centres, on évalue à environ 540 KWh par mois la consommation d'électricité de chaque foyer selon les appareils dont disposent les habitants de Hartley Bay. Or, le MAINC prévoit une consommation de 700 KWh. La consommation réelle par foyer s'établit en moyenne à 990 KWh par mois. La quantité globale d'électricité consommée dans le village dépasse d'environ 78% ce qu'elle devrait être.

- Une part importante de cet excédent doit être attribuée au chauffage des locaux à l'électricité, qui n'est pas permis. Par contre, le programme de tarification de l'électricité selon un taux mensuel fixe incite carrément à cette utilisation interdite de l'électricité.

- Parallèlement, comme on peut s'y attendre, la consommation de mazout est beaucoup plus basse que prévue.

- En fait, la consommation brute d'énergie de cette collectivité représente approximativement 80% de celle d'autres collectivités comparables, moins éloignées des grands centres.

- Comme une part considérable de la consommation de mazout est absorbée, fort mal à propos, par un groupe électrogène au diesel, à un degré d'efficacité global qui est bien inférieur à ce qu'il serait si les locaux étaient carrément chauffés au mazout, la consommation nette d'énergie utile est encore plus basse, s'établissant à environ 70%. En d'autres mots, le rendement de l'énergie consommée au sein de la collectivité est de 70% environ de celui d'une collectivité comparable, mais plus rapprochée des grands centres. Voilà dans quelle mesure la demande peut être considérée comme étant "plafonnée". Si elle ne l'était pas, on pourrait s'attendre à ce qu'elle augmente de jusqu'à 40% de plus que le niveau actuel de consommation nette d'énergie utile.

- Le scénario d'approvisionnement à petite échelle de Hartley Bay en hydro-électricité, (entre 500 et 600 KW d'énergie ferme), éliminerait pratiquement la consommation croissante de pétrole, qui est d'environ 440 000 litres par année. Ce plan ramènerait la population environnante au village et encouragerait peut-être l'industrie locale. De plus, en 14 ans, l'investissement serait amorti.

- D'autres possibilités de remplacement immédiat du pétrole affichant de courtes périodes de récupération sont suggérées. Aucune, toutefois, ne représente une solution complète en tant que telle. On peut s'attendre à une montée de la consommation globale d'énergie, plutôt qu'à une réduction de la consommation de pétrole.

En conclusion, le rapport suggère qu'avant de prendre d'autres possibilités en considération pour Hartley Bay, le MAINC devra décider s'il faut adopter le scénario d'alimentation en hydro-électricité.

Le rapport recommande aussi de lancer un programme de collecte de données dans d'autres collectivités éloignées afin d'en définir les courbes de consommation et de voir si elles offrent des possibilités analogues de remplacement du pétrole.

2.0 BACKGROUND

2.1 INTRODUCTION AND OBJECTIVES

Unless adequate measures are taken to reduce oil dependency, it is estimated that over the next 20 years, B.C.'s remote communities will consume over 112 million litres of oil (25 million gallons). The estimated cost of this form of energy, including capital, operating and maintenance, will be close to $170 million in 1983 dollars. The offshore value of the oil alone amounts to approximately $2.9 million per annum or $65 million over 20 years in 1983 dollars.

To reduce dependency on oil, the Department of Indian Affairs and Northern Development (DIAND) has an on-going policy of energy conservation; it has funded several studies and two demonstration projects for small scale hydro-electric generation plants in B.C. However, at many communities, hydro power is either technically or economically inpractical, or insufficient energy is available to meet the full demand of the community.

The objective of this study is twofold. Firstly, it is to identify energy conservation opportunities and appropriate alternative energy generation technologies, which may be available to any remote community to reduce its dependency on oil. Secondly, it is to establish a relatively simple computer model which will indicate the energy trends in the community, the benefits of any given related course of action, and its economic feasibility.

For purposes of this study, the Indian community of Hartley Bay has been selected as a typical example of a remote community that is heavily dependent upon diesel and heating oil for power generation and space heating.

All appropriate off-oil generation and conservation technologies were considered, to develop the most practicable system approach. Technology factors and energy economics have been evaluated in order to develop the preferred generation/conservation programs for Hartley Bay, as presented in Section 7.0.

Figure 2-1 and Table 2-1 indicate over twenty Indian Reserves in British Columbia which may be described as "remote". That is, they are over 50 km from a major community and are not connected to the provincial electrical or natural gas grids. Population data and information on power sources for these remote communities are shown in Table 2-1, which indicates that most of them depend on diesel electric power for energy. Energy demand for these communities can be as high as 1220 kWh per residence per month compared with a general B.C. average of about half this level, excluding requirements for space heating and hot water. (Additional energy use of a 40-gallon water heater would be about 540 kWh/month, and electrical space heating would use 1500 kWh/month.) This high demand, coupled with a high unit cost for energy, results in an ever increasing cost of diesel fuel for Indian communities.

In view of the high costs associated with diesel-based energy in Indian communities, there is a strong incentive to reduce unit energy costs using alternative, off-oil technologies and to reduce energy demand using conservation technology. Thus far, however, there has been little or no progress toward energy conservation in Indian communities.

DIAND is actively pursuing the possibility of B.C. Hydro supplying power to four of the largest remote Reserves - Kitkatla, Takla, Fort Babine and Hartley Bay.

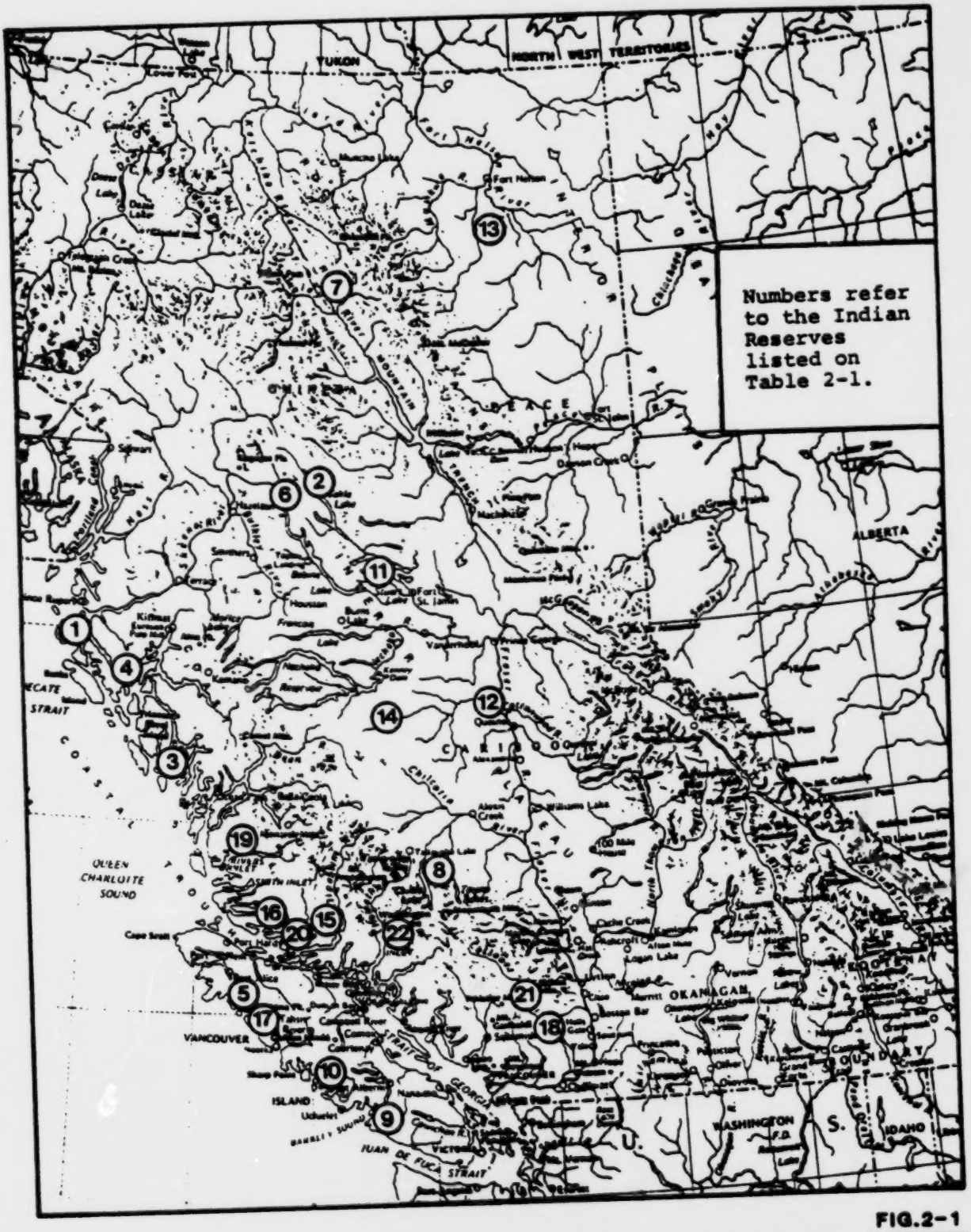


FIG.2-1

OFF-OIL ENERGY GENERATION & CONSERVATION

REMOTE INDIAN RESERVE LOCATIONS IN BRITISH COLUMBIA

ACRES

TABLE 2-1

REMOTE INDIAN RESERVES IN BRITISH COLUMBIA

COMMUNITY (RESERVE)	DIAND DISTRICT	POPULATION ON-RESERVE 1985	Trend	ACCESS	POWER SOURCE TYPE	kW	COMMENTS
1. Kitkatla (Dolphin Is. IR#4)	Northwest	500	+	Boat, float plane	D	1 x 400 1 x 300 1 x 150	
2. Takla Landing (Takla Lake IR#9)	Prince George	295	+	Rail, road; some planes	D	2 x 50	Supplies school and community facilities, not houses; stores have own diesel.
3. Klemtu (Kitasoo IR#1)	Vancouver	270	+	Boat, float plane	H (D	1 x 320 1 x 250)	
4. Hartley Bay (Kulkayu IR#4)	Northwest	240	+	Boat, float plane	D	2 x 150	
5. Kyuquot (Houpsitas IR#6)	Nanaimo	170	+	Boat, float plane	D	2 x 75	
6. Fort Babine (Babine IR#6 & 16)	Prince George	170	o	Plane, road			Two 7-1/2 kW diesels not functional; only school & teacherage hooked up.
7. Fort Ware (Fort Ware IR# 1)	Prince George	170	+	Plane, river boat	D	2 x 15	School, band office, store only
8. Nemaiah Valley (Chilco IR#1, 1A, 2, 2A, 3, 4)	Williams Lake	165	o	Road	D	2 x 10	Supplies Band office; off-Reserve school has own diesel plant.
9. Hitiaaht (Hatachen IR#11)	Nanaimo	150	+	Road	D D	1 x 75 1 x 67	
10. Hesquiaht (Hot Springs Cove IR#6)	Nanaimo	100	+	Float plane, water taxi	D	2 x 75	
11. Portage (Nemcut IR#1)	Prince George	80	-	Boat, float plane	D D	1 x 15 1 x 20	To school & teacherage only; many cables
12. Nazko (IR#2)	Williams Lake	75	-	Road	D	1 x 10	
13. Prophet River (IR#4)	Prince George	75	o	Road	D	2 x 35	School, teacherage, clinic and "limited" power to community
14. Kluskus (IR#1)	Williams Lake	70	-		D	1 x 2.5	Population spread over 5 Reserves.
15. Kingcome (Quaee IR#7)	Campbell R.	65	-	Boat, float plane	H D	1 x 75 1 x 75	
16. Gilford Island (Gwayasdums IR#1)	Campbell R.	60	-	Boat, float plane	D D	1 x 50 1 x 20	
17. Ehattesaht (Chenahkint (IR#2)	Campbell R.	55	o	Float plane, boat	D	1 x 20	Plant operates part-time
18. Douglas	Vancouver	45	+	Logging road	D	1 x 33	
19. Oulkeno (Katit IR#1)	Vancouver	35	-	Boat, float plane	D	2 x 55	
20. Hopetown (IR#10A)	Campbell R.	16	?	Boat, float plane	D	1 x 10	Plant operates part-time; only 5 houses in village.
21. Skookumchukch	Vancouver	22	-	Logging road	D	2 x 7.5	Community may be dying out.
22. Hamalco	Vancouver	0	o	Water taxi		-	Summer residents mainly.

+ Population increasing
o Population stable
- Population decreasing
D Diesel
H Hydro

This study has been prepared by Acres Consulting Services Limited (Acres) at the request of the Department of Indian Affairs and Northern Development, acting on behalf of the Hartley Bay Band. Funding for the study has been provided under the Remote Community Demonstration Program of Energy, Mines and Resources Canada, and from the Department of Indian Affairs.

The report is structured so that, where appropriate, each topic is discussed first in general terms relevant to any remote community. The general discussion is followed by an analysis of the topic as it applies to Hartley Bay in particular.

2.2 ENERGY CONSIDERATIONS IN REMOTE COMMUNITIES

Communities which are remote in terms of access to the provincial power supplies also tend to be remote in terms of transportation, education and access to supplies and outside services. A significant problem in power facilities at Indian Reserves is the frequent breakdown of equipment due to lack of routine maintenance and periodic overhauls. This results in inefficient operation and shorter-than-average life spans for the facilities. Therefore, the ease of maintenance is an important consideration in selecting a power supply tor remote communities.

On the one hand, simple technology has the advantage of being more readily understood by the members of the community, but a regular disciplined maintenance program is still necessary. On the other hand, a more sophisticated technology may allow the plant to run "by itself" most of the time, but when something does go wrong, help will be more difficult to obtain.

Remote communities will have basic energy requirements and expectations similar to those of urban communities. Fulfillment of these needs, the forms of energy used, and the level of consumption will, on the other hand, depend on various factors. These criteria include cost and availability of energy resource options, cost of energy production, facilities to operate and maintain sophisticated energy generation and delivery systems, and, ultimately, the socioeconomic standing of the community. These criteria are common to remote and urban communities alike. In the case of remote Reserves, energy usage is affected by additional factors such as government and Band pricing policies, incentive schemes and distribution arrangements. These policies influence the supply of electrical services and degree of implementation, subjects which are reviewed later.

In a recent survey (Sigma, 1983) of over 90 isolated communities in the province, including a number of remote Reserves, the energy options used for various heating purposes included oil, propane and wood, and (diesel) oil and small hydro for electrical energy production. A few of the Reserves were observed to have very limited electrical systems, with restrictions imposed on the daily hours of operation, while one or two of the smallest Reserves had no electrical supply. Some Reserves used no oil, relying on wood for heating. These variations are indicative of differences that can be expected to occur between Reserves.

2.3 HARTLEY BAY COMMUNITY

The Hartley Bay Indian Band is located at Kulkayu Indian Reserve #4 on Douglas Channel on the west coast of British Columbia (53°39'N, 129°17'W). The 1983 on-reserve

registered Indian population is estimated at 234; including non-Indian residents, the community population is about 250. Based on recent growth trends calculated by DIAND, the 2005 population is projected to be 318, a 35% increase over 1983.

The village has 67 residential buildings, a school, a Band office and a domestic water and sewer system. Power is presently supplied by two 150 kW Caterpillar diesel electric sets on a "one on load" with 100 percent standby. The peak loads on this system are regularly 110 kW in summer and 150 kW in winter (DIAND unpublished document, March 1982).

Access to Hartley Bay is by boat or float plane, the nearest major centre being Prince Rupert, 120 km away "as the crow flies".

3.0 ENERGY INVENTORY AND ANALYSIS

3.1 INTRODUCTION AND METHODOLOGY

As noted in Section 2.1, the objective of the study is two fold. Firstly, it is to identify conservation and alternative energy options for remote communities. Secondly, it is to establish a computer model which can indicate energy trends, the impacts of alternative courses of action and their economic feasibility. The latter module of the computer model should provide documentary justification for investment in the preferred option(s).

There are a number of energy-related computer programs available from various sources and with varying degrees of sophistication. However, they are generally oriented towards specific energy problems, or conservation in circumstances of high energy concentrations. Examples include industrial applications and energy use in large building complexes such as office buildings.

The model required in this study must be relevant to both the general circumstances encountered in Indian and other remote communities, as well as the most probable viable options at such locations. A viable option must be technically feasible to install and maintain under remote conditions, and economically feasible in comparison with the oil energy service.

To ensure relevance, a field trip of approximately two days duration was made to the chosen community of Hartley Bay, in mid-June, 1983. While a visit in winter might have been more useful, the timing was determined by the limitations of the study schedule. Specific objectives included:

- collection of energy consumption records and data on current energy resources being used;

- inspection of buildings, building uses, and construction details affecting energy consumption;

- determination of numbers and types of electrical appliances and heating equipment used, and review of electrical generation system;

- assessment of site-specific factors potentially affecting energy use and future energy resource options, such as general topography, layout of community, accessibility with respect to transporting and off-loading, and terrain influences on wind power;

- community plans for developing commercial or small industrial operations;

- any other factors which may affect the course of the study.

An initial meeting was held with the Band Council to present the study objectives and elicit suggestions, preferences, and insights specific to the community that could affect energy consumption and aid future conservation. The community diesel-electric system is owned and operated by the Band. Various details regarding the operation and adequacy of the system for meeting the power needs of the community were discussed.

During the course of the visit, the reconnaissance team conducted overview inspections of the school and other community buildings, and visited 14 of the occupied

residences. The assignment of a Band Council member to assist in making introductions with residents proved most helpful.

In order for the computer model to handle the broad range of oil-reduction options, it was evident that a systematic approach to field data collection would be necessary to establish the energy inventory and use. The computer model itself, and examples of print-outs, are described in Section 6.0.

Since space heating can be a major factor, and because related energy conservation is largely a matter of reducing heat losses, the consumption module of the computer model was extended to reflect various sources of heat loss in a variety of buildings.

To facilitate field collection and data analysis, buildings were divided into public and residential. Public categories, including school, commercial and community buildings, are dealt with broadly on a square- meter basis. Residential buildings, on the other hand, tend to fall into categories based on construction standards associated with their age. For inventory purposes, four classes have been established. These are designated Types X, A, B and C, which are described below.

- Type X is typically an older house, smaller than and not as well constructed as more recent housing. Doors and windows are poorly fitted and weather stripping is absent. Windows are single glazed and storm windows are not fitted. The building has no skirting and the insulation levels are low or non-existent. Exterior cladding may be deteriorating.

- Type A houses are typically of better quality than Type X; moderate levels of insulation are present in walls and ceilings but none in the floors. Skirting is in reasonable condition but may not always completely enclose crawl space. Windows are usually only single glazed, doors are not weather stripped and very few have storms installed.

- Type B is assigned to the best quality housing presently found in Hartley Bay. For this category the insulation is approximately R12 in walls and R16 in ceilings; some floor insulation is present, or the building skirting is complete and well constructed. Doors and windows are generally weather stripped and fitted with storms and windows are occasionally double glazed.

- Type C is assigned to housing built to CMHC's current highest standards of insulation and glazing, complete with storm doors and weather stripping.

  It may be noted that further categories of housing may be identified in the future, which are even more energy-efficient. For example, the Canadian Electric Association and Energy, Mines and Resources Canada (EMR) have developed recommendations categorized as the "Double E" certified Home, the "Super Double E" Home and the "R-2000" Home (See Appendix C). If any of these are subsequently adopted as standards for remote community building, they may, when fully defined, be added to the classification listing in order of energy efficiency.

The findings of the Hartley Bay inventory survey are given in Section 3.3.

As a result of the site visit at Hartley Bay and a preliminary examination of all possible oil reduction options, the following options were considered to be relevant to remote communities in general:

a) Conservation

- Energy management, i.e. better (or reduced) use and hence greater benefit from the forms of energy already in use. Generally, this can be achieved by information, incentives and appropriate pricing structures.

- Reduced wastage particularly in space heating, by improved insulation, vapour barriers and weather stripping. This can have dramatic effects for individual families. However, as existing housing stock is gradually replaced with new homes built to higher standards, the overall impact in the community will steadily lessen.

- Waste heat recovery from diesel generator plants, by a suitable recovery and distribution system.

b) Alternative Energy Resources

These options very much depend upon the availability of energy resources in the particular locality. As a group they depend on installing and operating a variety of equipment to harness and distribute the resource in question. Depending on location, potentially viable energy sources may include wood, small scale hydro, geothermal, wind, extensions of electric grid and natural gas pipeline, and so on.

Conservation options are discussed in some detail in Section 4.0, and alternative energy options in Section 5.0 and Appendix A1.

3.2 ENERGY DEMAND ANALYSIS

3.2.1 General

In order to assess oil reduction measures which may be appropriate for remote communities, it is necessary to establish current consumption patterns. Typically, sufficiently detailed records to document the total energy inputs and the end-uses will not be available for many villages. Even with the benefit of site visits and building inspections, details of energy consumption are not apparent.

A number of analytic steps are necessary to overcome the data deficiencies and to construct scenarios against which off-oil programs can be evaluated. To provide the conceptual framework for evaluating such alternatives, the following considerations must be addressed:

- extrapolation of surveyed energy consumption units to the total village;
- calculation of "typical" energy consumption and end-use patterns;
- population, household formation and other factors which will influence future consumption;
- energy supply prices;
- total energy costs to village.

In the case of remote Indian villages, analysis of residential energy requirements is the most difficult to quantify and yet likely to represent the most significant consuming sector. A detailed analysis of residential demand was therefore incorporated in this study.

3.2.2 Residential Demand

Household energy requirements can be generally divided into four end-uses:

(a) space heating;
(b) hot water heating;
(c) cooking; and,
(d) electrical appliances.

Space heating requirements are by far the most significant, followed by hot water heating. Net usable energy requirements have been developed for each end use. By using "net energy", it is not necessary to incorporate any complexities arising from energy source or conversion efficiencies at this stage.

To the extent that the energy requirements developed herein are based on provincial averages or other empirical observations, there is an implicit assumption that energy sources and prices in the remote community being investigated are equivalent to those in the rest of the province. Of course, this assumption will not be true in many cases and significant variances from the norm are likely to be observed in different villages. However, the use of broadly based averages does provide a mechanism for comparing and quantifying the patterns found in remote communities relative to other locales where normal market influences operate.

(a) Space Heating

Energy requirements for space heating depend chiefly on the physical composition of the envelope to be heated, the desired inside temperature, the outside temperature and the internal heat gains supplied by machinery, people, and other sources.

All of these variables are incorporated in heat loss calculations developed by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and have been utilized for the analysis described in this report. The estimated heat losses produced by this method compare quite favourably with average values used by B.C. Hydro and in the Sigma report (1983). The advantage of the ASHRAE estimates is that they are disaggregated according to the class of heat loss (i.e. infiltration, ceiling losses, etc.), whereas the B.C. Hydro and Sigma formulations provide only composite heat loss estimates, making it impossible to identify the relative importance of heat loss classes.

Table 3-1 provides the calculated heat losses for the four housing types (average values for each type) used in this analysis. The climate variable, "Degree Days", is 4000°C (7200°F) which correlates with the north coastal region. As can be seen, annual energy requirements range from over 111 GJ in the Type X houses to 57.3 GJ in Type C buildings. On a percentage basis, infiltration tends to be one of the greatest causes of heat loss. The infiltration calculation is based on assumed values for air exchanges which correspond with those used by B.C. Hydro. In the calculations, air changes ranging from 2 per hour in Type X houses to 0.5

TABLE 3-1
RESIDENTIAL HEAT LOSS VALUES

	HOUSE TYPE X			HOUSE TYPE A			HOUSE TYPE B			HOUSE TYPE C		
Area	70.60 m^2			92.50 m^2			97.60 m^2			111.50 m^2		
Height	2.50 m			3.14 m			3.69 m			5.00 m		
Window Area	15 %			15 %			15 %			15 %		
Degree-Days	4000°C			4000°C			4000°C			4000°C		
Cd Factor	0.65			0.65			0.65			0.65		
Air Changes	2.0			1.5			1.0			0.5		
	U*	MJ	%	U*	MJ	%	U*	MJ	%	U*	MJ	%
Infiltration	0.67	26,600	24	0.50	33,000	32	0.34	27,100	41	0.05	21,000	37
Windows/Doors	4.37	12,500	11	2.56	10,600	10	2.27	11,300	17	1.53	11,000	19
Ceiling	1.67	26,500	24	0.57	12,000	12	0.32	6,970	11	0.24	5,970	10
Floor	1.69	26,800	24	1.65	34,500	33	0.37	8,090	12	0.27	6,830	12
Walls	1.17	19,000	17	0.58	13,700	13	0.44	12,500	19	0.31	12,500	22
TOTAL MJ	-	111,400	100	-	103,800	100	-	65,960	100	-	57,300	100

* U-factor is stated in W/m^2-°C except for infiltration, for which it is W/m^3-°C.

per hour in Type C houses have been assumed. Finally, the U-factor captures the composition and heat loss resistivity of the building envelope. These have been calculated using a number of variables such as insulation levels, stud spacing, construction materials, and air movement at the surface.

With Type X houses requiring close to double the amount of energy of Type C houses to achieve basically the equivalent level of occupant comfort, it can be readily seen that insulation levels and construction methods can have a tremendous impact on the overall community energy consumption.

(b) Hot Water Heating

Estimates for hot water heating requirements are taken from B.C. Hydro average account calculations. Hot water usage does not vary according to house type. Net energy requirements for this analysis have been taken as 24.624 GJ (6840 kWh) per year per household.

(c) Cooking

Again, B.C. Hydro averages have been used for cooking requirements. Net energy for cooking has been assumed to amount to 4.32 GJ (1200 kWh) per year per household.

(d) Light/Appliances

Estimates of energy requirements for electrical lights and appliances have been developed from B.C. Hydro published averages, but modified somewhat to reflect the general stock of appliances found in the on-site energy inventory. The Hartley Bay inventory suggested

that some appliances, which are common in other areas, are relatively scarce in remote communities. When this is taken into account, an electrical demand of 22.264 GJ (6184 kWh) per annum has been assumed for lights and appliances. B.C. Hydro suggests that typical household consumption might be lower (19.872 GJ, 5520 kWh), but this figure is probably weighted down by relatively lower-consuming smaller households found in urban areas.

In summary, these four major end-uses for energy in the residential sector account for the "expected" net energy demand per household, given the housing types specified and the other assumptions noted. A further assumption is that households in remote Indian communities on the north coast of B.C. have consumption patterns roughly equivalent to those found in nearby regional centres such as Prince Rupert or Kitimat. Table 3-2 summarizes the estimated energy demand by end-use and housing-type.

These values are utilized in the energy consumption model discussed more fully in Section 6.0.

3.2.3 Non-Residential Demand

Typically, the non-residential buildings in a remote Indian village will consist of a school, Band office, community hall, general store, health clinic, perhaps a church, and other community buildings. These buildings will generally be constructed to similar standards as the residential buildings; several of them may in fact be houses which happen to have other uses.

Other sources of energy demand would include street lighting, water and sewer systems, and Band industries.

TABLE 3-2
RESIDENTIAL ENERGY DEMAND
(GJ)

END-USE	HOUSE TYPE			
	X	A	B	C
Space Heating	112	104	66	57
Water Heating	25	25	25	25
Cooking	4	4	4	4
Lights/Appliances	22	22	22	22
TOTAL NET ENERGY	163	155	117	108

In order to develop energy requirements for a given community, a combination of site-specific data collected in the course of field investigations, and some estimates to fill data deficiencies, are utilized. Typically, the energy purchases of the school board and the department of health can be obtained directly. Requirements for street lighting or water pumping can be calculated, based on observations of the installed equipment. Data on some of the Band-owned community buildings may be more difficult to obtain unless metering records are kept. Otherwise, demand can be estimated by treating these buildings as "household equivalents". For example, if there is a community hall or Band office building that is used relatively continuously, which is about twice the size of a residence, and which is Type B construction, it can be assumed to have the space heating requirements of approximately two Type B houses. Hot water requirements might be estimated at about one household equivalent. There probably will be no cooking requirements, and lights and appliances might be the equivalent of one household. In this fashion, the approximate requirements for non-residential buildings are estimated.

3.2.4 Energy Supply and Conversion

Once the requirements for net energy are developed as discussed in Sections 3.2.2 and 3.2.3 above, it is necessary to determine the gross energy demand by applying conversion efficiency factors. Again a combination of site specific data along with industry standards are applied. The site investigations will establish the mix of space heaters (oil, wood, electric) and their condition and relative efficiency. Similarly, the mix of types of cooking ranges, hot water heaters, laundry appliances, etc., can be established.

At the same time, it is critical to record the type and model and other particulars of the diesel generator, as the unit's conversion efficiency must be analyzed to estimate the gross diesel fuel requirements of the community.

With this site-specific data, the conversion factors are applied to calculate gross energy requirements. The conversions utilized in this study are given in Table 3-3.

With the gross energy requirements of the community calculated, it is possible to simply multiply the necessary purchases by the actual fuel prices to obtain the dollar requirements for energy in the community. This conversion to dollar amounts facilitates the economic evaluations of alternatives for the community.

3.2.5 Energy Projections

The final step in the demand analysis involves applying appropriate demographic projections to the energy consumption patterns in order to develop expected energy requirements for the future. Again, this exercise is useful for the economic evaluations since some energy alternatives can have economic lives which span decades, and it is necessary to understand how consumption will change over time.

The most critical demographic factors for projecting future demand are the overall rate of household formation and the mix in housing types. As noted earlier, residential consumption accounts for the bulk of the energy requirements in remote Indian communities, and the consumption per household is quite sensitive to house type. Therefore, DIAND policies with respect to housing improvement and construction, historical rates of population growth and household formation, as well as any anticipated changes in

TABLE 3-3
ENERGY CONVERSION EFFICIENCY FACTORS

RESOURCE	EQUIPMENT	HEAT CONTENT	CONVERSION EFFICIENCY	NET ENERGY
Stove & Furnace oil	.furnaces, ranges	39 MJ/L	0.55	21.45 MJ/L
	.pot burners	39 MJ/L	0.45	17.55 MJ/L
Diesel oil	.elec. generator	39 MJ/L	0.30*	11.70 MJ/L
Propane	.dryers, ranges, hot water heaters, furnaces	24 MJ/L	0.65	15.60 MJ/L
Natural gas	.dryers, ranges, hot water heater, furnaces	38 MJ/m^3	0.65	24.70 MJ/m^3
Wood	.stoves, furnaces	17 GJ/cord**	0.38	4.94 GJ/cord

* Assumes a relatively high efficiency generator producing 3.3 kWh per liter.

** Assumes wood with moisture content of 25 percent.

the community structure, will have a significant influence on future energy requirements. For the Hartley Bay case, the population and housing stock were projected to the year 2003, as presented in Section 3.3.3.

3.3 HARTLEY BAY INVENTORY

3.3.1 Electrical Generation System

The generation system is comprised of two 150 kW Caterpiller/Kato diesel generators located in a simple wood frame building on the Hartley Bay foreshore. Bulk diesel oil storage tanks are located above ground outside without containment dyking. The distribution system is 2400/120/240-V 3-phase, with step-down to 120/240-V to residences. The diesel generator units are about 5 years old; DIAND estimates the remaining life for these units to be at least 5 years. The units are presently arranged for individual operation only, with one unit on standby, and no paralleling options.

The climate at the time of the visit was mild to warm, conditions which would be expected to preclude any demand for space heating. Unit output was logged periodically using the non-recording meter in the diesel generator house. At 4:00 a.m., normally a minimum demand period, the unit load registered 65 to 70 kW (45 percent of rated load); at mid-day the load was 100 kW (67 percent); while at 5:00 p.m., approaching the normal peak period, the load was 110 kW (75 percent). This load (110 kW) was also witnessed at 11:00 p.m.

Under winter operating conditions, the Band Council advise that, at the peak demand times, residents are called upon to reduce usage to avoid diesel overload and shutdown. This suggests that a substantial weather-related space heating

demand occurs, a possibility reinforced by the presence of electrical heaters found in a number of homes.

Many of the buildings have facilities for metering electrical usage; however, usage is not recorded. Residential users pay a flat rate of $25/month, equivalent to 3.5¢/kWh for the assumed usage of 700 kWh/month. The provincial school board pays a fixed charge for the school's use of electricity; actual consumption is not recorded.

Approximately two-thirds of residential accounts were noted to be delinquent in the payment of the flat-rate charge. The average arrears period for each delinquent account was about 5 months.

3.3.2 Village Energy Supplies

Supplies of diesel, stove and furnace oil are periodically barged in. A common pipeline is used to distribute all three fuels from the unloading dock to storage. Separate storage facilities for diesel and community fuel oil are provided at the diesel plant, and at one or two buildings including the school and clinic. The Band Council is billed for all supplies with the exception of the school's, which is separately billed. Residents purchase fuel oil by the drum (205 L; 45 gal.) from the diesel plant storage facilities.

Oil storage facilites are also located on the dock float, principally to serve the community fishboats. The fuel used by the fishboats , small craft and land transport vehicles is not included in this study of community energy requirements. (Usage of land transport vehicles is particularly small, due to the absence of roads.)

Band Council and school board receipts for oil purchases provide a reliable record of the community's total oil consumption. However, a few residents purchase oil for home use from the dock during the spring and summer months. The amounts are not separately recorded, but the total is believed to be small.

No bulk propane deliveries are made to the village. Propane supplies, used for cooking and other home uses, are obtained by the fishboats during trips to Prince Rupert and elsewhere. Containers of 45-kg (100 lb) capacity are predominantly used in the community.

Table 3-4 presents, by energy resource, gross energy inputs and net or useful energy utilization at Hartley Bay. Oil consumption data are based on two years of records. Excluding that used for the school, heating oil quantities have been increased by a nominal 5 percent to allow for unrecorded purchases from other sources.

Propane and wood consumption values are much less reliable since they are based on memory of container purchases. "We use about 100 lb of propane every three months for cooking..." was a typical type of response. Wood consumption estimates given by residents are even less certain since quantities are not measured. Whereas oil consumption to the community can be fairly reliably quantified from the two central record sources, the propane and wood use data have been developed from a survey base of 14 houses, i.e. 24 percent of the 61 occupied residences (see Section 3.3.3). A simple pro-rating procedure has been applied on the assumption that these houses, selected at random, are representative of the community as a whole.

3.3.3 Buildings Survey and Projections

As shown in Table 3-5, there are presently 80 buildings in Hartley Bay Village consisting of 67 residential buildings plus community use and commercial buildings. It was apparent that it would not be feasible to carry out a complete survey of all buildings within the time allocated and it was therefore decided to survey the community use buildings and only a representative detailed sampling of the private residences. However, all houses were given an external visual assessment to classify them as Type X, A, B or C, as defined in Section 3.1; the results of the classification are also shown in Table 3-5.

The detailed housing survey was conducted using a standard printed survey form, a sample of which is included in Appendix A3. The survey sample consisted of 14 houses, selected so as to include Type X, A and B houses situated in random locations throughout the village. Fourteen sample houses were canvassed: 2 Type X, 8 Type A and 4 Type B houses.

Of the residences listed in Table 3-5, the two scheduled for demolition, the four unoccupied and the four under construction have not been considered in the energy consumption analysis. A triplex, which previously served as the teacherage, and the health clinic are not included in the residential house count but are considered for purposes of the analysis as equivalent to residences in the energy assessment. Two new teacherages were in the finishing stages of construction; these were not counted in the residential survey but are included in the overall village energy assessment for future projections.

TABLE 3-4
HARTLEY BAY ENERGY SUPPLY

RESOURCE	ANNUAL INPUT (L)	GROSS ENERGY (GJ)	CONVERSION EFFICIENCY (%)	NET SUPPLY (GJ)
Diesel Oil (Elec.)				
. Residential	220,000	8,850	30	2,574
. Other	40,000	1,560	30	468
	260,000	10,140		3,042
Heating Oil				
. Residential	114,000	4,446	50*	2,223
. School	42,000	1,638	55	901
. Clinic	7,000	273	55	150
. Other	18,000	702	55	386
	181,000	7,059		3,660
Propane				
. Residential	53,700	1,289	65	838
Wood				
. Residential	51 cords	663	38	252
		19,151		7,792

* Based on 50% of homes with oil furnaces (55% efficiency) and 50% with pot burners (45% efficiency)

TABLE 3-5
HARTLEY BAY INVENTORY OF BUILDINGS

Residential	
. Occupied	57*
. Unoccupied	4*
. Unoccupied (Slated for demolition)	2
. Unoccupied (Under construction, toward north of town)	4
Community Use	
. New Teacherages (1983)	2
. Health Clinic	1
. New School	1
. Old School (now Art Centre)	1
. Triplex (former Teacherage)	1
. Hostel	1
. Band Council Office	1
. Community Hall	1
. Church	1
Commercial/Other	
. General Store	1
. Diesel Generation House	1
. New Sawmill (Under construction)	1
	80

* The 61 residences available for occupation are comprised of:
Type X : 12
Type A : 34
Type B : 15

In addition to the buildings listed in Table 3-5, there are a number of miscellaneous buildings such as woodsheds and smoke houses. These have not been documented in the inventory.

Table 3-6 is a summary of the residential building survey showing floor areas, window and door areas, crawl space and basement data, window construction, and insulation and weather stripping for the three types of construction found in the village. The data have been averaged to give an indication of the typical features to be expected for the types and for the village as a whole.

Building Construction

Building construction is consistent with typical coastal Indian villages. In very few cases are buildings supported on concrete foundations, and there are few basements. Most houses are single-storey wood frame structures supported on wood pilings. The crawl space created by the piling supports is frequently left open. Sometimes this space is enclosed by a simple wood or, occasionally, sheet metal skirt brought down to ground level. The skirt is not well sealed to the ground and frequently is not continuous on all sides. The ground beneath the houses is usually quite damp and poorly drained, and often there is no attempt made to seal this off.

The main structure of the wood frame buildings is generally in quite acceptable condition. Seldom is there evidence of problems due to piling settlement. However, in a few houses the doors were noted to be poorly fitted, probably due to minor uneven settlement.

Exterior cladding is usually in reasonably good condition, although in some houses the cladding had not been completely installed, a condition that appears to have existed for a number of years. Vinyl siding appears to be the most popular with many residents and this material provides a good weather tight exterior, although a lack of attention to detail has in some cases been noted where the siding is poorly fitted and is sometimes coming loose. This siding is sometimes backed with a 5 to 10 mm thickness of insulating board. Following is a list of the various types of exterior cladding encountered during the survey:

- Aluminum siding
- Cedar siding
- Duroid shingles over shiplap
- Vinyl over plywood
- Vinyl over asbestos board
- Aluminum plus fibre board over plywood
- Cedar siding over tar paper
- Plywood on studs
- Cedar siding over plywood
- Aluminum plus insulation
- Vinyl siding over existing cedar siding.

Roofing is either duroid shingles or aluminum sheeting. Wood shingles or shakes were not in evidence on any buildings.

Insulation in houses is usually consistent with the age of the building. Older homes typically are not insulated but some have been retrofitted with nominal insulation in the ceilings. Newer homes usually have 75 to 90 mm of insulation in walls and ceilings. Some recently constructed homes have 150 to 200 mm in the ceilings. Many home owners reported that vapour barriers had not been used with the insulation. This is cause for some concern since, in one instance, recently installed ceiling insulation in an older home had to

TABLE 3-6
HARTLEY BAY HOUSING INSULATION INVENTORY

	TYPE X	TYPE A	TYPE B
Number in Survey	2	8	4
Floor Area (Average)	71 m^2	93 m^2	98 m^2
Below Floor:			
. Crawl space*	50%	70%	50%
. C.S. skirted*	100%	75%	50%
. Basement*	50%	30%	50%
Enclosed Volume (Average)	178 m^3	289 m^3	356 m^3
Insulation (R values):			
. Walls	6	10	12.5
. Ceiling	0	15	16
. Floor	3.5	1.5	3
Windows:			
. Area (Average)	12 m^2	14 m^2	14 m^2
. Aluminum*	-	50%	70%
. Wood*	100%	50%	30%
. Single-glazed*	100%	70%	70%
. Double-glazed*	-	30%	30%
Storm Doors*	-	30%	30%
Weather Stripping*	-	50%	100%

* Percentage of house sample with stated feature.

be removed when it became completely saturated from condensation.

Recently constructed community use buildings such as the new school, new teacherages, health clinic and Band office are well constructed to modern standards. These buildings are insulated to levels consistent with the standards prevailing at date of construction. The older community use buildings such as the old school, church and community hall have lower levels of insulation.

3.3.4 Appliance Inventory

In the course of the interviews with home occupants and the visual inspections of residential buildings, the stock of appliances was recorded on the survey questionnaire forms. A simple pro-rating procedure was adopted to extrapolate the energy consuming equipment expected for all residences in the village. Table 3-7 shows the results, with the equipment and appliances segregated by energy source (i.e. electricity, oil, propane and wood). Significant observations from Table 3-7 are as follows:

- a number of residences have more than one freezer (average of 1.3 per residence);
- only 15 percent of residences use electric or oil ranges for cooking, the remainder use propane ranges;
- 50 percent ot residences use electricity for hot water heating while 20 percent have no hot water heating;
- 60 percent have electric heaters, supplementing other forms of space heating;
- about 90 percent of the residences have oil burning heaters (furnaces or pot burners) while 20 percent use

wood as a supplementary heat source (of the 14 residences surveyed only one used wood heating exclusively).

Information regarding the type and capacity of electric heaters used for supplementary space heating was not readily available, though the majority are believed to be of the plug-in portable unit heater type. (One of the houses surveyed reported the use of three heaters.)

3.4 HARTLEY BAY ANALYSIS

3.4.1 General

The detailed analysis of energy inputs and end-use requirements relied on the inventory and field investigation data and on a computerized energy consumption model developed specifically to provide detailed information on energy requirements for remote communities. The underlying assumptions and structure of the model are discussed in Section 6.0. The results of model runs with respect to Hartley Bay are presented in this section.

As a result of these two streams of activity, two approaches to defining the energy profile of the village emerged. The field investigations were able to establish with reasonable accuracy the supply of energy resources to the village as well as gather various indicators of consumption. The modelling exercise on the other hand began with estimates of end-use requirements and derived a comprehensive demand picture for the village. The reconciliation and understanding of the variances in these two approaches has constituted the bulk of the analysis work and has yielded most of the significant conclusions.

TABLE 3-7
HARTLEY BAY RESIDENTIAL APPLIANCE STOCK
(Estimated from survey of 14 Hartley Bay residences)

	ENERGY SOURCE				Total	Avg. per Residence (61 Residences)
	Electricity	Oil	Propane	Wood		
Appliances:						
Lighting	61	-	-	-	61	1
Kitchen Ranges	4	4	53	-	61	1
Refrigerators	61	-	-	-	61	1
Freezers	78	-	-	-	78	1.3
Washers	61	-	-	-	61	1
Dryers	26	-	17	-	43	0.7
Dishwashers	4	-	-	-	4	0.1
Furnace Fans	17	-	-	-	17	0.3
Colour TV's	70	-	-	-	70	1.1
Toasters	44	-	-	-	44	0.7
Elec. Kettles	13	-	-	-	13	0.2
Fans	24	-	-	-	24	0.4
Coffee Makers	37	-	-	-	37	0.6
Irons	53	-	-	-	53	0.9
Stereos	45	-	-	-	45	0.7
Radios	69	-	-	-	69	1.1
Vacuums	41	-	-	-	41	0.7
Heating Equipment:						
Hot Water Heaters	30	13	5	-	48	0.8
Space Heaters						
- Furnaces	-	17	-	-	17	0.3
- Pot-Burners	-	39	-	-	39	0.6
- Electric Elements	39	-	-	-	39	0.6
- Wood Burners	-	-	-	13	13	0.2

The following subsections will discuss these approaches in turn, commencing with the supply picture.

3.4.2 Energy Supply (Inputs) and Conversion

As noted in the inventory data presented in Section 3.3, accurate records of oil deliveries to Hartley Bay were available. It could be assumed that all diesel oil went through the electrical generator while heating oil (stove and furnace) was dedicated primarily to space heating and some cooking and hot water heating. Propane and wood delivery data were less reliable.

A major concern in the analysis was the estimation and distribution of electrical energy. As noted previously, neither electrical output nor consumption is metered at Hartley Bay. Electricity production is, therefore, dependent on estimates of diesel generator performance. B.C. Hydro sources indicate that for medium speed diesel units of this size, the specific output could vary from about 2.9 kWh/L to 3.5 kWh/L depending on the average load on the system. The manufacturer's engine and generator performance data for the 50-100 percent load range indicates expected specific outputs of 3.1 to 3.5 kWh/L.

Extensive records, necessary to assess actual conditions more precisely, are not available. From accounts of high system loads experienced during the winter, the extensive use of hot water heating, the presence of electrical heaters in more than 50 percent of the houses, and the load demand witnessed at the time of the June reconnaissance visit, it is inferred that the system is operating with a high annual load factor. This would result in the diesel generator operating closer to its design duty point with benefit to fuel consumption (improved specific output).

For study purposes an average specific fuel consumption of 3.3 kWh/L is assumed, leading to the estimated annual electricity production of 858,000 kWh/yr shown tabulated in Table 3-8. Electrical consumption estimates for the school, the street lighting and various community services are also indicated. Residential consumption is shown by difference. The estimate for the school is based on electrical installation drawings indicating a connected load of approximately 18 kW for lighting and 15 kW for mechanical room equipment and miscellaneous ventilation fans. The estimate of street lighting consumption is based on the use of 50-175 W mercury vapour lamps. The value for the community store is based on the use of large food freezers, three of which are of the open food-display type. Table 3-8 concludes with an indicated average electrical energy consumption of 11,800 kWh/yr for each occupied residence, or 980 kWh/month.

Table 3-9 presents electrical consumption breakdowns for the statistically average residence in Hartley Bay. The energy requirements are based on a weighted average of the actual appliance stock found in Hartley Bay and using B.C. Hydro published average consumption values for the various appliances. The resulting annual consumption for lights and appliances is 6500 kWh (23.4 GJ). This assumes that no space heating, hot water heating or cooking is done with electrical energy.

However, comparison with the estimated actual consumption of 11,800 kWh (42.5 GJ) indicates that, on average, 5300 kWh (19.1 GJ) are being used for these purposes. Since there are only 4 electric ranges estimated to be in the village, but 30 electric water heaters and 39 space heaters, it can be assumed that the bulk of the excess electrical consumption

TABLE 3-8
HARTLEY BAY ESTIMATED TOTAL ELECTRICAL PRODUCTION & CONSUMPTION

ELECTRICAL PRODUCTION	
Annual Fuel Consumption	260,000 L/yr
Overall Specific Output	3.3 kWh/L
Annual Energy Production	858,000 kWh/yr
System Annual Load Factor	60%
Average Annual Load	90 kW

ELECTRICAL CONSUMPTION	kWh/yr
School	70,000
Street Lighting	29,000
Band Offices	8,000
Hostel (limited use)	2,000
Church & Community Hall	4,000
Clinic (excluding staff residence)	3,000
Store	15,000
Miscellaneous Services (including water supply & sewage pumps)	10,000
Total, Community Facilities	138,000
Annual Energy Production (from above)	858,000
Residential Energy Consumption (by difference)	720,000
Average Consumption per Occupied Residence	11,800

TABLE 3-9
HARTLEY BAY RESIDENTIAL ELECTRICAL CONSUMPTION*
(Statistical Average Residence Basis)

Appliances:		kWh/month
Lighting	(1.0** x 70***)	70
Refrigerators	(1.0 x 150)	150
Freezers	(1.3 x 120)	156
Washers	(1.0 x 15)	15
Dryers	(0.7 x 75)	52
Dishwashers	(0.1 x 40)	4
Furnace Fans	(0.3 x 50)	15
Colour TV's	(1.1 x 30)	33
Toasters	(0.7 x 20)	14
Elec. Kettles	(0.2 x 22)	4
Fans	(0.4 x 8)	3
Coffee Makers	(0.6 x 12)	7
Irons	(0.9 x 4)	4
Hi Fi	(0.7 x 11)	8
Radios	(1.1 x 4)	4
Vacuum	(0.7 x 3)	2
		540

Annual Consumption	KWh	GJ
. Lights & Appliances only	6,500	23.4
. Actual Consumption (Table 3-8)	11,800	42.5
Difference	5,300	19.1

* Assumes household requires electricity only for allowable purposes; that is, no space heating, cooking or hot water heating on electric.

** From Table 3-7

*** From B.C. Hydro, "Household Appliances: Average Energy Consumption".

goes to these units. B.C. Hydro estimates that a typical household using electrically heated hot water requires 540 kWh per month. Therefore, on a weighted average basis, about 60 percent of the excess consumption can be explained as follows:

(30 water heaters/61 residences)	= 0.49
(.49 x 540 kWh x 12 months)	= 3175 kWh
(3175 kWh/5300 kWh)	= 60%

This assumption would then leave an average of (5300-3175) = 2125 kWh (7.6 GJ) per household per annum being applied to supplemental electric space heating. This is the equivalent of each house operating one 1000-watt electric space heater an average of 5.8 hours per day, year round. Nevertheless, this heating load represents only a small fraction of typical total space heating requirements. Therefore, the bulk of the heating energy in Hartley Bay remains oil-based.

3.4.3 Energy Consumption (End-Uses)

The energy consumption model developed for this study generates estimates of energy requirements by sector and end-use based on calculated values of net or usable energy. Appendix B2 provides a print-out of a model run using the indicated particulars for Hartley Bay.

Basically, the model uses the actual housing stock at Hartley Bay, along with the projections of appliances in the village and the indicated assumptions for the non-residential buildings, to calculate net demand. Then, assumed conversion efficiency factors thought to be typical for Hartley Bay are applied to produce gross energy requirements along with the dollar values for these purchases. All energy amounts are stated in gigajoules (GJ).

In the non-residential sectors, the buildings were classified as follows:

School:	Type B Construction 2 household equivalents for hot water Electric demand specified at 230.4 GJ
Commercial:	General Store Type A Construction No hot water Electric demand specified at 54 GJ
Community Buildings:	Old School, Church & Community Hall Type A Construction 2 household equivalents for hot water Electric demand specified at 46.8 GJ
	Band Office, Hostel & Clinic Type B Construction 3 household equivalents for hot water Electric demand specified at 68.4 GJ
Street Lighting:	Electric demand specified at 104.4 GJ

As can be seen from the print-out, the expected energy consumption for a village having the same structure and building stock as Hartley Bay is estimated at about 145 GJ per annum per household for the residential sector (60 household units). The corresponding market price for this energy is about $3200 per year. With the total village requirements included, these figures rise to 184 GJ and $4100 respectively.

The projected 145 GJ per household is somewhat higher than the average of about 125 GJ for coastal regions. This is primarily explained by the high proportion of poorly insulated Type X and Type A houses in Hartley Bay which have inordinately high heat loss values.

A further assumption in the model is that all space heating and water heating energy is provided by heating oil combustion, cooking is provided by propane combustion, and lights and appliances operate on electrical energy. This breakdown should approximate the most efficient energy conversion and be typical of communities where consumers face the actual costs of energy resources.

The model, therefore, describes what would be expected in a remote community much like Hartley Bay. To understand more about the actual energy consumption profile of Hartley Bay, it is necessary to compare the model results with the actual inputs discussed in the previous section. Table 3-10 illustrates this comparison. The actual energy figures are derived from Table 3-4, which provided the identified energy inputs to the village. The model results are taken from the print-out in Appendix B2.

Several remarkable points are highlighted in Table 3-10, especially in the variance and ratio columns. Firstly, residential electrical consumption is 1333 GJ greater than would be expected. The ratio indicates the actual consumption is over twice that calculated as the norm by the model. However, for residential heating oil consumption, the actual consumption appears to be only 31 percent of the expected requirement, or a shortfall of close to 4900 GJ. Overall, this analysis indicates that the total village consumption is only about 70 percent of what would be expected at comparable communities.

Given the pricing structure faced by Hartley Bay residents, it is not surprising that, where possible, there has been a substitution of electric consumption for oil consumption. Neither it it surprising that, on balance, given the number of relatively poorly insulated houses, oil consumption is short of what would be expected in the model. The model assumes all space heating and water heating is on oil and the model includes enough oil to heat even Type X houses to standard comfort levels. What is in fact happening, is that much of the water heating is on electric energy and the Type X houses are probably not routinely heated to what most people would consider comfortable levels.

Another interesting point arising from Table 3-10 is the comparison of overall conversion efficiencies. Due to the distorted consumption pattern in Hartley Bay, the energy conversion factor is only 40 percent versus an expected value of 46 percent. This result is caused by the substitution of electric power with a conversion efficiency of 30 percent for heating oil with an efficiency of 50 percent. This inefficiency is depriving the village of about 1055 GJ of energy, or about one-third of the projected short fall, simply by using energy resources for the wrong end-uses.

Other discrepancies in Table 3-10 are of less significance. The non-residential requirements in the model indicate some significant variances from the actual, but these have little overall impact on total village consumption. Also, the model assumes propane is only used for cooking while, in fact, other uses such as clothes-drying and water heating do occur, accounting for the higher actual consumption. The model does not incorporate the contribution of wood as a supplemental source of space heating energy.

TABLE 3-10
HARTLEY BAY ENERGY CONSUMPTION PROFILE

SOURCE	ACTUAL		MODEL		VARIANCE	RATIO
	Gross Energy (GJ)	Net Energy (GJ)	Gross Energy (GJ)	Net Energy (GJ)	Net Actual minus Net Model (GJ)	Net Actual: Net Model
Diesel Oil (Elec.)						
. Residential	8,580	2,574	4,136	1,336	+1,333	2.07
. Other	1,560	468	1,560	468	-	-
	10,140	3,042	5,696	1,709	+1,333	1.78
Heating Oil						
. Residential	4,446	2,223	14,192	7,096	-4,873	0.31
. School	1,638	901	798	439	+ 462	2.05
. Clinic	273	150	)		)	)
. Other	702	386	) 2,796	1,516	) - 980	) 0.35
	7,059	3,660	17,746	9,051	-5,391	0.40
Propane						
. Residential	1,289	838	399	259	+ 579	3.23
Wood						
. Residential	663	252	-	-	+ 252	-
TOTAL	19,151	7,792	23,841	11,019	-3,227	0.71
OVERALL CONVERSION EFFICIENCY		40.7%		46.2%	-6.1%	0.87

TABLE 3-11
HARTLEY BAY RESIDENTIAL ENERGY ANALYSIS

END-USE	Actual Net Energy (GJ)	Model Net Energy (GJ)	Variance (Actual minus Net)	Ratio (Actual: Net)
Lights and Appliances:				
Electric Consumption*	2,574	1,241	+1,333	2.07
Less: Hot Water Heating (30 units x 24.6 GJ)	(738)			
Space Heating (39 units x 7.6 GJ)	(297)			
Cooking (4 units x 4.3 GJ)	(17)			
Adjusted Total Appliances	1,522	1,241	+ 281	1.23
Heating, Hot Water and Cooking:				
Oil Consumption*	2,223	7,096	-4,873	0.31
Plus: Elec. Hot Water	738			
Elec. Space Heating	297			
Elec. Cooking	17			
Propane	838	259		
Wood	252			
Adjusted Heating, Hot Water & Cooking	4,365	7,355	-2,990	0.59
TOTAL RESIDENTIAL ENERGY	5,887	8,596	-2,709	0.68

* From Table 3-10

Table 3-11 provides a reconciliation of the energy inputs and actual consumptions for the residential sector. With the adjustments indicated, the distortions in end-use consumption are at least partially explained. When hot water and space heating and cooking are deducted from the actual electrical consumption, it is determined that consumption on lights and appliances is still high but somewhat less extreme than the unadjusted totals.

Similarly, when these adjustments are made to the oil consumption figures, and wood and propane use are added in, the total energy applied to heat, hot water and cooking comes up to a more reasonable 59 percent from an unrealistically low 31 percent.

Still, total consumption remains near 70 percent of expected levels. Again, a note of caution is required in interpreting this figure. The model indicates what energy is required to heat a comparable village with the same housing stock mix as Hartley Bay. In reality, however, if normal economic pressures existed in this comparable village, such a housing stock would probably not exist since it would simply be too expensive to supply energy to such poorly insulated buildings. Accordingly, as the lower quality houses in Hartley Bay are abandoned and replaced by Type C buildings, which is expected to occur on a fairly rapid schedule, the 70 percent actual to model ratio should quickly approach unity. The impact of these changes is analyzed in Section 3.4.4 on energy consumption projections.

3.4.4 Future Requirements

In order to evaluate the adequacy and potential benefit to be derived from longer-term energy alternatives in Hartley Bay,

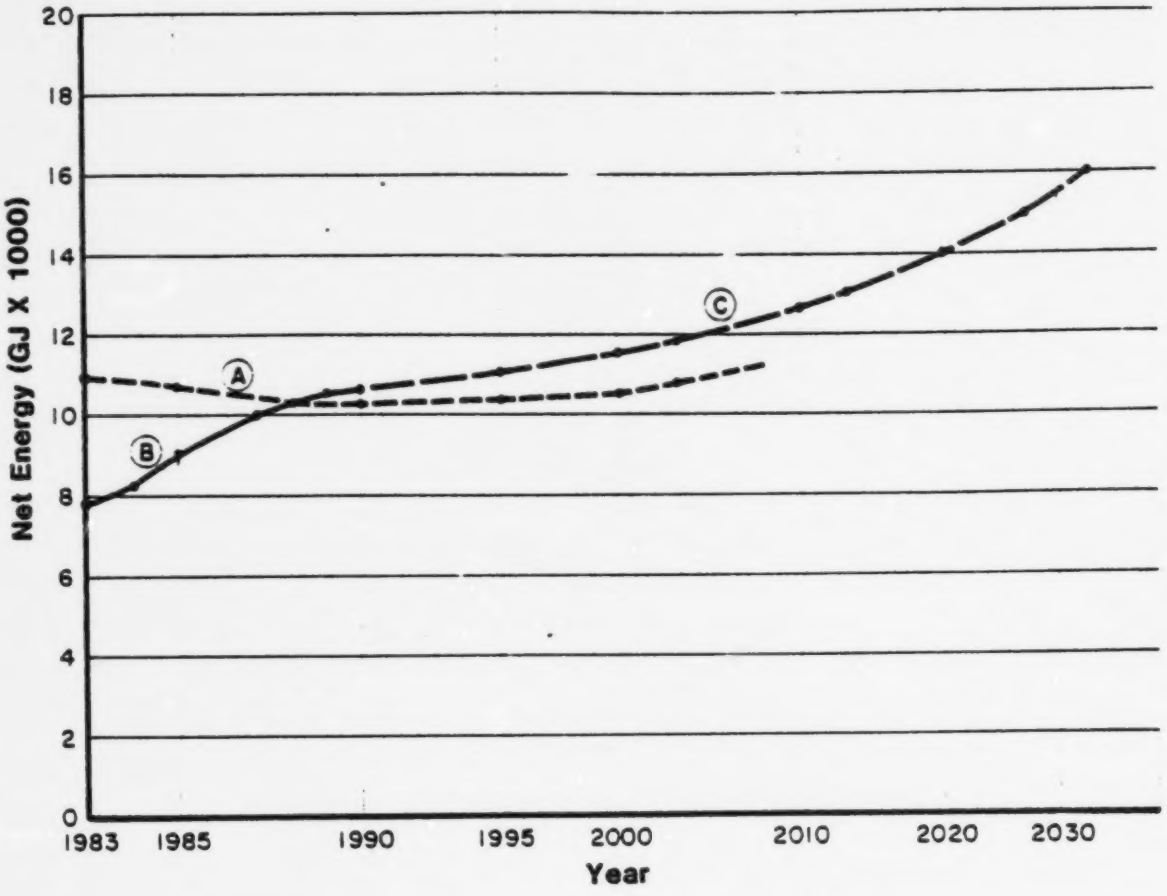
it is necessary to project the demand that must be met and the associated oil consumption that could be displaced. A demographic projection module has been developed as part of the computer model applied to this study.

Starting with the current population and mix of housing stock in Hartley Bay, the model calculates annual population and housing mix changes. Appendix B1 shows the projections for Hartley Bay to 2003. The growth rate and house replacement assumptions used in the model are listed at the top of the table.

Village population is projected to grow about 28 percent to 300 over the next 20 years. This assumes, however, that there is not a major change in growth rates such as might be expected if energy became inexpensive and plentiful in Hartley Bay. Such circumstances might encourage many of the off-Reserve band members to return, thereby generating a significant jump in population.

It should also be noted that the projection module assumes that all future housing construction in Hartley Bay will be to Type C (energy efficient) standards. This has significant impact on the energy consumption projections since the poorly insulated houses are assumed to be demolished fairly quickly and a dramatic reduction in energy requirements for space heating purposes results.

The demographic projections for Hartley Bay have been applied to the energy consumption module to project energy demand. Figure 3-1 illustrates the results. Appendix A4 provides selected printouts of computer runs for the years 1985, 1990, 1995, 2000 and 2003.



LEGEND

A — EDF Model - nonresidential sector remains static

B — Expected "catch-up" due to improved energy availability in Hartley Bay

C — EDF Model Expected Case - 2% nonresidential growth until 2003, 1% total growth thereafter

FIG.3-1

OFF-OIL ENERGY GENERATION & CONSERVATION

HARTLEY BAY : PROJECTED ENERGY REQUIREMENTS

ACRES

To indicate the impact of the constantly improving housing stock predicted for the community, Curve A is included in Figure 3-1 to isolate changes in the residential sector. With non- residential sectors being held constant, the EDF model runs actually show a decline in net energy requirements to 1990 despite the fact that population is expected to grow at a rate of 1.5 percent per annum through this period. Annual demand stays in the range of about 10,300 GJ to 11,000 GJ over the next 20 years, recovering to 1983 levels only at the end of the period.

It should be noted that the model is based on the assumption that energy supply is not constrained. As discussed earlier, however, such is not the case at Hartley Bay. The capacity for electrical power generation is capped, and it is probably just not practical to heat Type X houses to the comfort levels applied in the model. As a result, Hartley Bay consumption is only about 70 percent of the model's typical consumption level.

However, it is expected that there will be strong growth in energy requirements over the next few years as a result of improved energy availability and the rising expectations of community residents. Therefore, a "catch-up" period can be anticipated if energy availability becomes less constrained. This expected high growth phase is indicated by Curve B in Figure 3-1. Demand growth on the order of 5 percent per year between now and 1990 would bring Hartley Bay consumption to non-remote community norms. A catch-up period of shorter duration would results in much faster growth.

The expected demand projection includes the catch-up phase to 1990 and some modest growth in the non-residential sector. Certainly, as population increases, it would be expected

that school space, commercial space, community buildings, and so on, would also increase. The expected case beyond 1990 includes 2 percent growth in non-residential sectors to 2003 and 1 percent to 2033. The 1 percent growth rate is also applied to the residential sector after 2003 since housing stock improvements will not be offsetting population increases by that time. This "expected case" is depicted in Curve C in Figure 3-1.

The time frame to 2033 is included since the hydro-electric option for Hartley Bay is assumed to have an economic life of 50 years. The expected case results in a total demand of 16,100 GJ by 2033. Using a capacity factor of 65 percent, indicated sizes for hydro-electric plant to supply Hartley Bay are about 575 kW to 2003 and 785 kW by 2033.

4.0 CONSERVATION OPTIONS

4.1 INTRODUCTION

Conservation of energy can be achieved by two approaches. The first is by energy management, which involves little investment but requires a conscious effort to take an active on-going role in conserving energy. The second is energy conservation, which involves making specific investments in more energy-efficient systems, or in the installation of heat-loss prevention measures such as improved insulation.

Energy conservation refers to the prevention of unnecessary loss of energy. Those areas in which the greatest savings or benefits are likely to be made are in space heating of buildings and in hot water supply. The heat input required to maintain a building at a comfortable temperature must balance the rate of heat loss. The rate of heat loss is a function of the difference between inside and outside temperatures, the surface area of the building, and the effectiveness of the insulation. To reduce the temperature difference and thus the heat losses, it is necessary to lower the inside temperature. This may require the sacrifice of some comfort but it can usually be made acceptable by the wearing of warmer clothing, use of additional bed blankets, elimination of drafts, closing of window drapes, etc. These actions should rightfully be classed as energy management.

The surface area of conventional rectangular or square buildings cannot be significantly reduced without affecting the internal space, which in turn is usually dictated by building usage. However, the energy-conscious party will recognize that the smaller the building, the lower the heating costs, and will endeavour to keep the building space to a minimum. Multi-usage areas can contribute significantly

to this feature. Ell- or Tee-shaped buildings are inefficient with respect to space-to-surface-area ratios and should be avoided where energy conservation is a prime concern.

4.2 ENERGY MANAGEMENT

Energy management requires an awareness, by persons involved, of the sources of energy waste or loss and the methods available to reduce losses. In the private residence these can take the form of controlling indoor temperatures, setting back thermostats at night, minimizing hot water usage, turning off lights, televisions and other appliances when not required, closing doors and windows when heating units are operating, cleaning furnaces, etc. Some improvement in energy management can also be achieved by the introduction of more efficient equipment. Examples include lower consumption freezers and appliances, high efficiency furnaces and high/low space heating timer controllers. However, some of this equipment is relatively expensive and not readily serviced in remote areas.

An important factor in the implementation of successful energy management is the incentive element. Energy saving practices are not likely to be continued unless the occupant can experience some form of direct benefit to himself, either financially or by way improved living conditions. Benefits accruing to the village at large may be only marginally effective except for the most community-minded of individuals. In the commercial or industrial sector of the community, energy management can be applied in similar ways to those affecting residences. In addition, savings can be made by sequencing of high energy usage in order to reduce peak electrical or system demands. In community and commercial buildings, recycling of air to the maximum

permissible can be employed when the buildings are unoccupied. Night-time lighting can be substantially reduced and automatically controlled; street lighting can be adjusted to minimize the "on" time.

4.3 INSULATION

4.3.1 General

The basic principles of building insulation are generally quite simple and fairly well understood by most people. However, proper attention must be given to numerous small details in order to achieve a truly energy efficient building. Basic structures with simple exterior and interior cladding have an insulating quality in themselves, though of relatively low value. The addition of only 45 to 50 mm thickness of insulating materials to walls and ceiling of the basic structure will more than double the insulation level. Filling up the stud space (usually 90 mm) in walls, and the joist space (usually 140 mm) in ceilings will double again the previous insulation value, and triple the value for an uninsulated buildings.

Insulation restricts the circulaton of air (convective currents) within the wall and ceiling spaces, which then prevents the transfer of heat from warm interior surfaces to the colder exterior. It also retards the direct escape of warmed interior air. Insulation of exterior walls, ceilings and floors should always be installed with an effective vapour barrier; this barrier is placed on the warmer side of the insulation layer, i.e. the living area. Without this barrier, warm interior air travels through the insulation layer, becoming cooler in the process. Eventually it will reach a point, usually within the insulation, where the air

is sufficiently cooled for the contained water vapour to condense. The insulation becomes progressively saturated until it is rendered ineffective. The properly installed vapour barrier serves a second valuable function: in preventing the migration and condensation of moisture, it also prevents the direct escape of warmed air. At the same time it prevents the infiltration of cold, draft-producing outside air. Care must be taken during the installation to ensure that the vapour barrier forms a complete and continuous film over all interior surfaces and that there are no areas left uninsulated. For example, small spaces between framing members, particularly adjacent to door and window frames, must also be packed with insulation.

It is noted that frequently at remote Indian villages, the buildings are not founded on conventional concrete or masonry foundation walls, but are supported on wood pilings. Occasionally there are fully enclosed basements, but usually the space below the main building floor is either completely exposed or only partly enclosed by a skirt wall. This wall is usually of very simple construction, and is not well sealed. There are several possible alternatives to providing insulation at this significant source of heat loss. The decision on the method will depend largely on the end-use intended for this crawl space beneath the building. Probably the most effective method is to completely enclose the crawl space by providing well constructed, sealed skirt walls. These walls would then be insulated. Moisture from the exposed ground can cause rotting of wood floors and joists, and it is necessary to take steps to prevent this happening. Either the ground may be sealed over or vent openings may be provided in the skirt walls to ensure adequate ventilation. Vents, however, defeat the main purpose of the skirt wall; that is, to reduce heat losses through the building floor. Sealing of the ground may be accomplished by first smoothing

the surface, removing debris and projections, and then laying 4 or 6 mil polyethylene sheeting directly on the ground. This material should be lapped, 200 mm minimum, at joints and made continuous with the insulation vapour barrier applied to the walls. The wall insulation should be brought down to the ground level and extended several feet over the ground sheeting. The sheeting may be held in place with bricks or stones if the crawl space is not to be used, but if the area is to be used for storage or as a semi-basement, the sheeting must be protected with a skim coat of concrete or a properly leveled concrete floor. An alternative method of reducing heat loss is to provide insulation at the underside of the floor between the floor joists. In this case the skirt wall may be omitted, although skirt walls do have considerable aesthetic appeal. The floor insulation must be installed with a vapour barrier placed toward the living area. Special care must be taken at the perimeter to make the insulation as continuous as possible with the wall insulation. Also care must be taken to seal around plumbing and electrical openings in the floor.

Windows and doors usually represent the largest single source of heat loss in residential buildings. The percentage loss from this major source can be from 30 to 50 percent of the total building losses, depending on other insulation levels. The losses associated with windows and doors originate from two sources. The first is the direct radiant and conductive losses through the materials, and the second is from infiltration of cold air through cracks and spaces around the perimeter of the openings. Direct losses through windows can be best reduced by double or triple glazing, by installing storm windows, by providing inside shades or drapes, or by various combinations of the above. Losses can be reduced fourfold by triple glazing plus storm windows as compared with single glazing. Shades can make further reduction in

losses. The losses that occur through doors can be reduced by exchanging hollow core doors for solid core and by adding well fitted storm doors. The losses associated with air leakage around doors and windows can be minimized by ensuring that all cracks between frames and wall construction, and between frames and windows, and doors are well sealed and caulked. Windows that open, and doors, should be provided with carefully installed weather stripping. Door sills should be fitted with weather stripping seals. Storm doors should also be weather stripped. The above-noted methods to prevent air leakage, when combined with carefully placed vapour barriers, can reduce heat losses from infiltration fourfold.

4.3.2 Hartley Bay

Table 3-6 summarized the field observations and arrived at sample averages for insulation characteristics in Hartley Bay. Care must be taken, however, when adopting such averages, particularly in the case of older construction. For example, two Type X houses were inspected. One had estimated R12 wall insulation and R7 floor insulation, all assumed to be retrofit; it formerly had ceiling insulation, but this had to be removed due to severe condensation resulting from a lack of vapour barrier. The second house was completely uninsulated. This illustrates that wide fluctuations in specific instances can be expected.

Type A and Type B houses showed progressively less disparity in insulation characteristics. The more recently constructed buildings, i.e. the health clinic, teacherages, triplex and school, all appear to have reasonable levels of insulation.

As has been noted in Section 3.2.2, residential space heating is the major consumer of energy. Conservation in this area consists of reducing heat losses, which in turn requires

careful attention to building detail. The best opportunity for this, at least cost, is during original construction. The latest recommended standards of insulation, vapour barrier, weather stripping, etc., should be adopted for all new construction. (i.e., R20 in walls and floors, R28 or better in ceilings). Just as important is ensuring that workers on site understand the importance of good workmanship and attention to detail during installation, particularly with regard to insulation and vapour barrier continuity.

Improving the heat retention by the many existing building envelopes requires extensive retrofit. Dramatic improvements can be achieved in obvious and specific instances to the benefit of individual residences. Broadscope reduction of heat consumption on a long term basis, however, is not so easily accomplished. This is because each house requires individual examination and attention to specific detail.

Obvious cases for improvement are the Type X houses. However, at Hartley Bay there is already a policy of replacement. As the computerized demographic projection in Appendix B1 show, all Type X houses are expected to be phased out by 1985.

Reference to the Total Energy Costs in Appendix B2 shows that the highest costs (and the most obvious opportunities for heat loss reduction) appear under the demand classes of "Floor Losses" and "Infiltration" for the Type A houses.

Where floor insulation is combined with a properly installed vapour barrier, the loss from air infiltration is also greatly reduced. Since the inside surface temperature of the floor is permitted to rise, the "feeling" of warmth is greatly enhanced, with a consequent reduced need to maintain

high space temperatures. Where no insulation and vapour barrier exist, even coarse or cheap carpeting laid over 4 mil polyethylene sheeting is highly beneficial.

Insulation batts with an attached tar paper vapour barrier on the upper side installed between floor joists is more effective. However, it is more expensive and more difficult both to put in place and keep there.

An alternative to underside floor insulation is to install sealed and insulated building skirts. While not quite so effective, this approach does provide a better exterior appearance and possibly some additional dry storage space. However, sealing over the damp ground (whether by polyethylene film or a thin layer of concrete) is essential to avoid wood rot.

Some 40 to 45 houses in Hartley Bay could benefit substantially by adding some form of floor insulation.

Benefit would also be obtained from insulating ceilings in those homes where none exists at present. In this case, a vapour barrier is also essential and must be on the underside of the insulation. Otherwise the insulation becomes saturated from moisture condensation, not only rendering the insulation ineffective but also causing ceiling damage. Opportunities here appear to extend to about 8 or 9 houses in the village.

Perhaps 90 percent of the homes could benefit from a program to reduce heat loss due to cold air infiltration. This involves adding well-fitted weather stripping to doors and windows which open, caulking cracks around door and window frames, and ensuring continuity of vapour barrier where

possible. Most of this work, however, tends to be of a recurring nature and is part of the upkeep of any building.

The addition of storm doors and windows contributes substantially to the reduction of heat loss through these areas. However, retrofit tends to be relatively expensive compared to the gain in benefit.

4.4 DIESEL WASTE HEAT RECOVERY

4.4.1 General

Diesel generator units convert about 30 percent of the fuel energy to electrical energy. The remainder appears as follows: approximately 30 percent as waste heat distributed to the jacket cooling water/radiator system, 30 percent to exhaust, and 10 percent in general radiation losses. Waste heat recovery of both the cooling water and exhaust heat allows up to 80 percent of the fuel input energy to be utilized. All of the jacket cooling water heat and about half of the exhaust heat can be recovered. Heat exchangers transfer jacket and exhaust heat to secondary cooling loops. These recirculation loops transport the heat energy to end-use points. The jacket-water waste-heat recovery system can provide heat as hot water, at up to 120°C, or as low pressure steam (1000 kPa, 15 psig). The higher temperature exhaust heat recovery system can provide hot water or, alternatively, steam at pressures up to 1000 kPa (150/psig). Jacket water heat recovery providing high-temperature hot water is the simpler system and is more commonly adopted. However, a single secondary hot water loop can be designed to retrieve some of the exhaust gas waste heat.

With any arrangement of diesel waste heat recovery, the amount of productive heat available is dependent on diesel output, which is in turn set by the electrical system load demand. For space heating applications the demand for heat is determined by outside ambient conditions.

Since the electrical and space heating demands are not necessarily in phase, independent standby heating facilities are still required during periods of diesel shutdown, low loads and peak heat demands. On the other hand, to suit low or zero heat demands, a radiator (or other exchanger) is required for jacket cooling.

Table 4-1 provides an indication of the waste heat available annually at annual electrical load factors of 40 and 60 percent, assuming one-third of the fuel energy is recoverable. Average specific output of 3.3 kWh/L, and fuel heating value of 38.3 MJ/L are also assumed.

Since waste heat is available year-round, whereas space heating requirements are seasonal, perhaps only 70 percent of the available waste heat could be effectively utilized. For an average residential demand of 90 GJ/yr, say, waste heat could accordingly meet the demands of 25 to 40 percent of residences, depending on the electrical system load factor.

Retrofitting of jacket waste heat recovery with an existing diesel system is generally readily accomplished. Ideally, a single or limited number of large users or heat, located in reasonable proximity to the diesel plant, are required to minimize the scope and installation cost of the secondary loop hot water transport system. The community school would be a prime candidate at most Reserves, followed by the teacherage, Band office, other high use community facilities,

TABLE 4-1

DIESEL WASTE HEAT AVAILABILITY

Design Output (kW)	Annual Generation (kWh/yr)		Waste Heat Availability (GJ/yr)	
	40%	60%	40%	60%
50	175,200	262,800	670	1005
100	350,400	525,600	1340	2010
200	700,800	10,512,000	2680	4020

and perhaps some adjacent residences. A community-wide hot water distribution system tends to be uneconomic although with very high oil costs, such as those experienced at some remote Reserves (Sigma, 1983), this conventional wisdom could well be reversed.

4.4.2 Hartley Bay

The opportunities for diesel waste heat utilization appear to be quite good. The principal candidate is the new school, which has an apparent annual demand (net) of over 1000 GJ/year. About 50 percent of the 150 kW diesel jacket waste heat output could be utilized by the school. Routing from the diesel plant to the school is fairly direct and passes a number of closely packed residences, the clinic, Band office, community hall and the triplex teacherage. The existing heating methods in these buildings would be retained for standby purposes and peak heating, if found to be necessary.

A community oil saving potential of 80,000 - 120,000 L/year is possible. Insulated hot water supply and return lines can be conveniently slung under boardwalks, avoiding burial and cost problems. Selection of a hot water supply temperature of approximately 80°C could permit the use of some plastic pipe; steel would be appropriate for vulnerable exposed sections. A preliminary evaluation of the technical and economic potential of this energy conservation option is recommended.

4.5 SITING

4.5.1 General

Appropriate siting of buildings to take advantage of naturally occuring topographic features can often contribute

considerably to their energy efficiency. Heat losses can be reduced significantly by locating on the leeward side of hills or mountains, or in sheltered ravines. Experimental houses have been constructed partially underground against a sloping land faces to improve the sheltering effect from prevailing winds. Better use can be made of solar energy by constructing on south-sloping land. Traditional building designs must usually be modified to make the most of the naturally occuring features.

Shelter from wind can also be provided by artificial mounds or by trees, although trees will be only marginally effective unless they are dense, closely-planted and occur over a considerable belt width on the windward side.

Although judicious selection of siting may prove beneficial for a few individual cases where there is relatively free access to a variety of siting options, it will not usually be possible for a significant percentage of houses to benefit much in a single community. Indeed, most existing villages are laid out on a simple rectangular grid, with little or no apparent consideration for either sheltering effects or potential solar gain benefits, the choice of subdivision configuration and location probably having been made against more mundane criteria such as simplicity of layout, cost of construction and cost of servicing. There is much to be said for the simple traditional layout. Whereas careful selection of siting may prove beneficial for isolated cases, it will not be generally attainable for entire communities.

4.5.2 Hartley Bay

For existing communities such as Hartley Bay, very little can be done by way of siting modifications to improve the energy

picture. Even for new subdivisions, the benefits are likely to be only marginal for the best siting locations and will be negligible for the majority of cases. Planting of windbreak trees and shrubs in new subdivisions is also likely to have only minimal benefit. Advantage should be taken wherever possible of natural or artificial measures to conserve energy; however, in most instances, the options available are not likely to be cost effective.

4.6 HEAT PUMPS

4.6.1 General

The heat pump operates on refrigeration principles, removing energy from a low temperature source and discharging it at a higher temperature. High grade energy (electricity or mechanical work) is supplied to the process to maintain this flow of energy. The quality of high grade energy needed increases with the temperature difference required. For space heating applications, the heat energy delivered is in the range of 2 to 5 times the electrical energy input. Clearly the heat pump saves energy relative to direct electrical resistance heating. However, where electrical energy supplied is generated from the combustion of fuel (e.g. diesel generator), the efficiency of fuel conversion to electrical energy will be only about 25 percent. In this case, the overall energy saving from heat pump operation is either much reduced, or may be negligible, relative to the direct combustion of fuel in space heating facilities. In general, the economics of heat pump operation do not compare favourably with other forms of heating unless a low cost source of electricity is available. The major benefit of the heat pump is that the same equipment can be used for cooling in summer as well as heating in winter.

Packaged heat pump equipment suitable for individual residences is available. The system requires a source of low grade heat. A large water body is the ideal medium. The atmosphere can be used but both heat-pump capacity and efficiency decrease at a time when heating requirements increase, as the outdoor temperature drops. In addition, the frosting of air coils can be a problem.

4.6.2 Hartley Bay

The relative technical sophistication and need for servicing precludes the use of heat pumps at remote communities such as Hartley Bay. In the general case, heat pumps will not offer an economic solution to residential space heating needs. Providing a pumped supply source of low temperature water (sea, lake, ground water) adds to installation and operating costs.

5.0 ALTERNATIVE ENERGY RESOURCE OPTIONS

5.1 INTRODUCTION

This section presents a summary of the various energy resource options and technologies addressed in more detail in Appendix A1, and concludes with a judgement of the potential of each resource for Hartley Bay. The evaluations have been undertaken with specific regard to practical factors which affect their adoption at remote Reserves. These factors include: resource availability and security of supply; proven state of the technology; skill levels required for operation and maintenance; and costs (where available). Uses of the resource for both electrical generation and heating are considered, as appropriate. Certain more advanced but less well established technologies such as liquefied natural gas and methanol from wood fibre were omitted from the study on the basis of the factors noted.

The recommendations regarding the competitiveness and suitability, or otherwise, of a resource for use at remote Reserves in general, and Hartley Bay in particular, can only be tentative under the broad scope of this study. Where a resource option looks promising at any given location, its adoption should be preceded by a specific technical and cost evaluation to justify the expenditure. Such evaluations should normally include an examination of the lifecycle cost implications.

5.2 HYDRO-ELECTRIC

5.2.1 General

Development of an economically viable hydro-electric scheme is very much dependent on the natural occurrence of a proper combination of certain essential physical conditions. The

prime requirement is for an adequate supply of water at a sufficient elevation or "head" to generate the necessary power. The energy available (kilowatts) at a given site is directly proportional (except for minor variations in plant efficiency) to the product of the quantity of water and the "head".

Those features of a potential site having greatest influence on costs are the installed capacity, topography of the site hydrology of the site, required length of transmission line and the degree of accessibility of the site.

5.2.2 Hartley Bay

The Indian village of Hartley Bay is ideally situated with respect to the potential for development of a hydro-electric power supply. Recent studies (e.g. Acres, January 1983) have identified numerous promising sites in the vicinity of the village.

The sites identified are especially attractive since they offer a wide scope for development capacities. These range from several potential sites which individually would barely meet the present needs of the village to at least two sites which could produce power far in excess of the most liberal estimates for future load growth. Although Hartley Bay is very fortunate in having numerous hydro-electric options available, care must be taken to make the most economic selection. In spite of the fact that several of the schemes thus far identified show quite favorable cost/benefit ratios within the context of small or mini-hydro, the costs for energy are still relatively high when compared with the large-scale generation costs enjoyed by users on the main B. C. Hydro grid. With this in mind, it is extremely important to ensure that the site ultimately selected and the

capacity to which it is developed is carefully matched to both the present needs and the long term future projections for load growth, in order not to overtax the limited financial resources of a small community. In making a choice of the options available, sites with a good possibility for future expansion should be given preference over those with a fixed or limited potential.

Numerous possible hydro sites have been located to date, all within 7 km of Hartley Bay. Of these, two main sites have been identified as most closely meeting the village requirements. One site is located between the upper and lower lakes on the Hartley Bay River. The hydro scheme could be developed in a number of ways to produce from 130 kW to slightly over 400 kW firm power at ultimate development. To develop the higher potential of this scheme requires diversion of one river system into another, but the environmental impact of this diversion has not yet been addressed. The second site is located on Hawkesbury Island across Douglas Channel to the east of Hartley Bay. This scheme will produce at least 500 - 600 kW firm power, which is considered to be more than adequate for all the village requirements into the foreseeable future. The scheme utilizes a small amount of water from a very high elevation lake. Transmission across Douglas Channel to the village requires a 5 km long submarine cable. Approximately 3 km further north from the Hawkesbury site there is another site with about equal potential which could be considered for possible expansion in the distant future. Other schemes, associated with Gamble Lake about 12 km northwest of Hartley Bay, have been identified as having potential for up to 3000 kW firm power, much more than any future requirements for the village.

At the present level of investigations, it is believed that the Hawkesbury Island site offers the option best suited to meet the hydro-electric needs of Hartley Bay. The estimated cost of energy is reasonable and the indicated potential plant capacity just suits the projected village requirements. However, it should be pointed out that at present, the various options have been investigated at only the pre-feasibility level of design, and that more definitive studies must be made prior to making a final commitment to construct any of the hydro schemes.

5.3 WIND

5.3.1 General

Opportunities for exploiting wind energy are most favourable in B. C. along the west coast of Vancouver Island and the Mainland coast, though suitably exposed sites will exist in the interior of the province.

More than 40 small Wind Energy Conversion Systems (WECS) are operating in the province, mainly of 2 kW or less. A 50 kW output demonstration unit on Vancouver Island is under investigation by B.C. Hydro. This is the general size of unit appropriate to remote community needs. For technical reasons the WECS is required to operate in parallel with a diesel unit (or other power source); a standby diesel is also required for security of supply. The WECS acts principally as a fuel saver and, for economic justification, is required to provide energy that is competitive with the fuel cost component of diesel generation, typically 15¢ to 20¢/kWh. Today, a 50 kW WECS, installed at a remote Reserve and achieving a 25 percent annual load factor, could be expected to generate energy at 40¢ to 50¢/kWh (see Appendix A1.3).

Achieving cost competitiveness with diesel generation is considered to be many years away, given conservative assumptions regarding future oil prices. On the other hand, WECS technology in the size of units appropriate to Reserves should be technically proven in the next few years. Development progress and cost trends should be reviewed at intervals of perhaps five years.

5.3.2 Hartley Bay

The general analysis (see Appendix A1.3) indicates that WECS is not a sufficiently proven or competitive option, relative to diesel power, and is therefore not appropriate for Hartley Bay.

5.4 WOOD

5.4.1 General

Wood and wood-wastes are available in abundance but transportation to user points is an economic restraint. Wood-fired electrical generation technology is technically proven, but requires sophisticated skills for operation and maintenance. To suit the needs for small scale generation of remote Reserves, it is prohibitively expensive.

Therefore, the principal application of wood as an energy resource is in residential space heating. Cut wood harvested locally by the community can be used, preferably in the more efficient controlled-air type of wood stove. This is considered to be a practical and potentially economic option for most communities.

However, obtaining sufficient supplies of wood to meet total residential heating needs is often a constraint to increased

wood usage. Rugged and inaccessible terrain are typical conditions that curtail or prevent the use of land transport for individual hauling.

A community-sponsored harvesting operation, on the other hand, perhaps requiring some initial capital funding assistance and training of personnel, may be appropriate to overcome collection and delivery constraints where little wood is currently being used. Such a community-organized supply of wood for sale to residents could overcome the difficulties faced by individuals in retrieving wood in quantity from the local forests. In addition, it should be pointed out that such a scheme would provide an opportunity for local employment within the community.

Heating energy costs are about half that of oil heating, given a selling price of $65/cord. For B.C. coastal conditions, a mature forest area of about 0.06 ha requires clear-cutting annually to meet the average single residential space heating demand.

5.4.2 Hartley Bay

Most of the wood used in the village is salvaged from the sea. The village fishing boats haul back to the village drifting logs that have come from forest operations on the coast. This free source of supply is uncertain and availability will probably decline as forest operations make greater use of special purpose barge containers for timber transportation.

The present Hartley Bay total space heating needs would require an annual cut of about 2000 m^3 (850 - 900 cords) representing close to 900 tonnes of wood. Assuming a clear

cut harvesting operation, about 3.5 ha of forest would be cleared annually.

The terrain surrounding Hartley Bay is wooded, rugged and rises steeply on either side. Inland to the west, the land is covered with muskeg and is sparsely wooded, rising gradually over some distance to higher areas. Wood supplies would have to be obtained from outside the immediate vicinity of the community, probably recovering timber from the steeply wooded slopes along the Douglas and Grenville Channel coastline. Towing of cut timber to the community could be accomplished with the boats available or a special-purpose vessel, depending on the economics and structure of the collection operation.

A small sawmill facility is in the process of construction at the community. An extension to this facility could be developed for cutting, splitting, and storing logs. No significant technical constraints appear to stand in the way of the development of this renewable energy resource. The question is whether the operation and use of the wood would be socially acceptable.

5.5 GEOTHERMAL

5.5.1 General

Geothermal hot springs provide a potential source of hot water for meeting community hot water and space heating needs. The technology is simple and straightforward, comprising pumps, heat exchangers, and insulated pipework systems. The principal factors affecting the potential for this resource are:

- proximity of hot spring and temperature of the source;
- terrain conditions between hot spring and community;
- extent of the community distribution system required and complexity of retrofit requirements; and
- peak heating load.

These all affect the installation cost. The average cost of heat energy will be reduced by two factors:

- a high annual heat demand (high load factor)
- maximum annual utilization of sensible heat in the hot water supply (large temperature drop).

In a number of countries, including the western U.S., geothermal hot water from deep sources has been employed for many years in space and domestic water heating applications. Development costs for surface hot spring sources is significantly less than that for deep sources.

Energy costs are entirely site-dependent preventing any useful generalization vis-a-vis competitiveness with oil or other forms of heating. Nevertheless, a recent study (Acres, March 1983) has shown that a number of geothermal direct heating applications are capable of economically displacing both oil and electricity. Deep resources, with temperatures of 60° and up, and involving high development costs, were considered in that study.

5.5.2 Hartley Bay

Although the Geothermal Potential Map of B.C. (B.C. Ministry of Energy, Mines & Petroleum Resources, 1983) indicates a hot spring source in the vicinity of Hartley Bay, the inhabitants appear to have no knowledge of it. A number of remote sources are to be found on the opposite shore of the Douglas Channel. The absence of a local geothermal surface in the immediate vicinity of Hartley Bay excludes this resource as a possible form of energy source.

From follow-up discussions with Energy, Mines and Petroleum Resources and a review of the original source study (Goodbrand and Crandall, 1977), it appears that this is an "alleged" hot spring source of which there are a number shown but not differentiated on the Geothermal Map. The source is shown located about 3 km north of the community on the bank of the Douglas Channel. In view of its status, no other information is available concerning important parameters such as flow rate and source temperature. If a source of suitable thermal quality can be substantiated, its proximity to Hartley Bay is a potentially attractive feature. A review of the local topography at a 1:250,000 scale suggests that routing to the village may be quite straightforward. A source of 50°C and 4 L/s would provide useable thermal energy in excess of 1 GJ/h with a potential of saving 8 bbls/day of heating oil. For source temperatures less than about 50°C a geothermal-heat pump combination could be economically atttractive. A preliminary level investigation, clarifying the existence of the hot spring source, its thermal potential, and possible application, is probably justified.

5.6 GASIFICATION

5.6.1 General

Gasification is a fuel conversion technology. It entails the production of low to medium heat-value gas by burning coal, wood or peat under oxygen-starved conditions. The gas produced is suitable for firing in a conventional boiler or, after clean up, in an internal combustion engine.

Coal gasification is a costly, complex, large-scale, developmental technology inappropriate for remote community applications. However, wood gasification is technically proven on a very small scale as evidenced by its use for vehicle operation as a matter of necessity, during the Second World War. Comparatively recently, two foreign manufacturers, Duvant and Imbert, have developed wood gasification systems for use with modified internal combustion engines. Duvant is regarded to be the leader with a downdraft gasifier and modified dual-fuel diesel engine having a 460 kW or 720 kW output capability. Automatic control features regulate the operation of the combined plant under a variety of fluctuating load and gas quality/quantity conditions.

The main concerns in remote community use are with wood supplies and the wood preparation and handling aspects of gasifier operation. The issue of wood supplies has already been addressed in Section 5.4. Wood preparation equipment is required to reduce bulk supplies to useable form, i.e. wood chips or small blocks. As noted by Crippen (1982) commercially available wood chipping equipment is designed for treating sawmill wastes. A typical unit's throughput of about 30 m^3/hof solid wood would support a gasifier installation output of about 3000 kW and consume up to 150 kW of power. This indicates that in the practical gasification

size range, such equipment is too large, so that there is a need for a smaller chipper to match with gasifier requirements. Storage and handling facilities are also high-cost maintenance items, vulnerable to blockages and freezing, and requiring full time operator attendance (Ontario Hydro, 1982). Such factors are not insurmountable but, relative to diesel generation, generally do require a much greater commitment to plant operation and maintenance. A dual-fuel-fed diesel engine is possible and has the advantage that, by switching to the diesel mode, wood feed problems need not interrupt electrical supply.

Matching the community load demands to either of the two design capabilities of the Duvant system (460 kW and 720 kW) would require many remote communities to convert either entirely or substantially to electric hot water and space heating, including the school.

Smaller capacity gasifier systems and combustion engines are being developed, some in North America. However, these have yet to attain the same level of proven performance and reliability, that has been achieved by the Duvant system, and which is necessary for electrical generation.

The Ontario Hydro study (1982) reviewed gasifier lifecycle economics. It concluded that the technology will only be competitive with diesel generation for larger installations (nominally 500 kW or better) at remote sites, provided that:

- substantial wood (or peat) resources are available at low cost;
- an electrical load factor of 50 percent or better can be achieved.

Compared to straight diesel generation, wood gasification will remain a more complex and potentially vulnerable system.

Given favourble wood supply conditions and confirmation of the technical and economic viability of a gasifier operation under remote conditions, a demonstration program based on use of the Duvant system (or equal) might be justified.

5.6.2 Hartley Bay

Wood gasification for remote Reserves would need to be analyzed in greater depth, before it could be considered as a practical technology for Hartley Bay. Wood harvesting and preparation, staffing, training and organizational issues would all require detailed examination. Certainly the present community's total energy demand appears adequate for an all-electric conversion on a Duvant plant scale of output.

5.7 COAL

5.7.1 General

The technology developed for coal-fired electrical generation or steam production is fairly sophisticated and expensive, and reserved for large scale plants. For remote Reserves its practical application is for direct heating, using controlled-air stoves. Coal delivery is one of the principal restraints to coal use at remote locations.

Coastal communities are accessible by barge from the Vancouver or Prince Rupert coal ports. The present rail deliveries of domestic coal from Alberta are small scale

operations, quite separate from the major coal export activities in the province.

A tentative analysis of coal delivery costs (Appendix A1.7), including barge delivery but excluding a component for final off-loading at a community, indicates that residential heating with coal should be competitive with oil.

However, it is considered that with the abundant wood resources available in B.C., the development of wood use in remote Reserves is a more likely off-oil option than coal. Wood collection from local sources would also provide an employment opportunity for the community which is not matched with coal use.

5.7.2 Hartley Bay

Barge deliveries of coal to the community are technically practical. One annual shipment of 600 tonnes or so would be sufficient for present needs. However, off-loading and transport to storage presents some obvious difficulties. The community layout, local topographic features, absence of roads and the use of boardwalks make access from the dock awkward. An open area does exist behind the community which might be used for coal storage, but an access route from the dockside which avoids the village is not immediately apparent.

These constraints, the unacceptability of coal as a common source of fuel, and the more readily available wood supply, make coal an unlikely energy source at Hartley Bay.

5.8 SOLAR ENERGY

5.8.1 General

The available solar energy on an annual basis is relatively constant for most of British Columbia. The exceptions are the coastal areas including the Queen Charlottes and Prince Rupert locations, which receive 15 to 20 percent less solar energy than most other areas. The daily average available energy over the year for an optimum sloping surface varies from 12 MJ/m^2 to 15 MJ/m^2.

Solar energy systems are used for home space heating, hot water systems and for direct conversion to electricity by photovoltaic cells. For remote communities the practical applications are for space and hot water heating. Even these require substantial and costly building modifications or installations to take best advantage of the potential energy savings. Both applications require good insulation and careful energy management to prevent heat wastage and hence to gain maximum benefit from the installation.

Solar space heating is usually a passive system in which building modifications are made to the building and insulation levels are increased in order to capture as much solar energy as possible on the one hand and to minimize heat losses on the other. Building modifications usually consist of increasing window areas on southern exposures while reducing them on northern faces. Windows are usually double glazed to reduce heat losses, although single glazed windows in combination with night insulation is slightly superior. Similarly, triple glazing will not produce as much net heat gain as double glazing with night insulation. Night

insulation usually consists of insulated shutters or sliding doors which can be closed over the windows at night.

5.8.2 Hartley Bay

Solar energy records are not available for Hartley Bay, nor for any nearby communities. However, it is considered that available solar energy would be at least 20 percent less than the provincial average, due to climatic conditions alone. In addition, there may be some early morning and late afternoon shielding by local mountains which would effectively reduce the effective daylight by 1.5 to 2 hours. Existing homes at Hartley Bay would not particularly lend themselves to the retrofitting of large solar windows. Since a passive system may yield only 15 to 20 percent of the typical heat load it would appear to make better economic sense to upgrade the insulation levels.

For future homes, some consideration should be given to take advantage of solar energy contributions. In some case the house orientation may be adjusted to receive the most solar benefit. However, again it is not felt that extensive deviations will be made in housing designs to accommodate solar heating in the unsophistical remote communities. It is felt that the best gains can be made by ensuring that the housing is properly and fully insulated.

5.9 BIOGAS

5.9.1 General

Biogas production uses organic waste materials in an anaerobic fermentation process to produce a medium heat value gas of 20-25 MJ/m^3. It is two-thirds methane. The process

is well developed in countries such as India and China. It is generally associated with animal farming, so that its application in remote B.C. Indian communities is limited by the absence of sufficient quantities of organic waste.

5.9.2 Hartley Bay

A central biogas digested system, receiving the community biological waste materials only, would produce a net gas daily output equivalent to about 3 or 4 litres of diesel fuel in heat content. This form of energy production is not considered to be appropriate for Hartley Bay.

5.10 NATURAL GAS AND PROPANE

5.10.1 General

Connection to the natural gas supply network would satisfy much of a community's energy needs. By definition, this option does not exist for "remote" Reserves, due to the uneconomic distances and difficult terrain involved.

Propane appears to be used mainly for cooking and, to a lesser extent, for hot water and clothes dryer heating applications. Remote communities must transport relatively small capacity containers to external propane depots for filling. The development of bulk delivery and storage facilities is hindered by technical and economic factors, including accessibility for bulk propane transporters (barge or truck), and the higher cost of propane energy relative to oil.

Propane prices experienced by remote communities vary considerably with a resulting variation in unit energy costs

(i.e. $/GJ). Typically, these range from 20 to 100 percent higher than the cost of oil. Under comparable conditions, there is no economic incentive to displace oil with propane for space and hot water heating.

Propane for cooking and refrigeration, however, can be cost-competitive compared to marginally priced diesel electric energy, though this is off-set to some degree by the higher initial cost of propane appliances. The user who is subject only to a flat-rate charge for electricity and unrestrained use would pay considerably more to see propane appliances.

If electric ranges are displaced by an extensive use of propane cooking ranges, this clearly helps to reduce the load on the diesel-electric system. More important is the reduction in peak electrical demand that normally occurs between 5 and 7 p.m. with the coincident use of electrical cooking applicances. Propane appliances can help to reduce the electrical system capacity requirements when sized to peak loads and thus deferring the need for capital outlay required for system expansion.

5.10.2 Hartley Bay

For most residents of Hartley Bay, access to propane supplies is difficult and inconvenient. Its delivery is dependent upon the cooperation of the community fishboat operators, who arrange for filling a number of containers during trips to Prince Rupert or other propane sources. The cost, if any, to residents for this casual service is not known. However, the cost of fuel alone for the round sea journey to Prince Rupert is about $500, so that a specially-scheduled trip would add considerably to the delivered cost of a regular propane supply. With the present cost structure of propane,

even in bulk, it is difficult to justify any significant program of increased use.

As noted earlier, the use of propane cooking appliances does help to protect the electrical system from extreme peaks of demand on system operation during winter.

5.11 GRID EXTENSION

5.11.1 General

The electric grid system owned by B.C. Hydro, together with the smaller grids of West Kootenay Power and Light which serves south-central B.C., and the Alcan grid which serves the Kitimat area, provide electrical power to most residents of British Columbia. Inter-ties between these grids provide for load sharing, power exchange and continuity of service in case of line outages.

While most remote communities, by definition, are many miles from the nearest existing grid system, some may, in fact, be close enough for a grid extension to be feasible. The voltage level of the particular grid may be a determining factor. Even though a village is relatively close to a main grid, it is usually found to be too costly to step down from very high voltage lines in order to supply small communities.

The cost of a grid extension is, of course, mostly determined by the length of line required, the type of terrain and to a lesser but nevertheless significant extent, the transmission voltage level required. Longer lines usually dictate higher voltage levels and thus higher costs. However, since the cost of stepping voltages up and down at the sending and receiving ends of the line are more or less constant in this

respect for a given capacity, the unit cost per kilometer of grid extension may well remain nearly constant. This leaves construction difficulty as the main variant. As with any major investment, it will be necessary to analyze carefully the economics of grid extension in each case. However, it could be possible to develop a "rule of thumb" criteria to determine the limit to which a grid extension might be feasible based only on community population, local industry potential, distance and terrain.

A number of governmental agencies have in the past conducted programs to assist communities to improve their energy supply options. However, recent budget restraint has curtailed grants available from many of these programs. Nevertheless it is understood that the Rural Electrification Assistance (REA) program, established to help remote communities finance tie-ins to the main electric grid, may still be available through B.C. Hydro. (Sigma, 1983)

5.11.2 Hartley Bay

The nearest grid to Hartley Bay is at B.C. Hydro existing small hydro-electric plant at Falls River. This is located approximately 50 km southeast of Prince Rupert. The hydro site has recently been the subject of fairly extensive recent studies by B.C. Hydro, with the objective of better utilization of the site potential. The existing plant, although quite old, is connected to the main B.C. Hydro grid and so could provide a firm, reliable source of power.

The length of a transmission line from Falls River to Hartley Bay is approximately 75 km. The terrain appears to be medium to difficult, but not extremely so. On a very preliminary basis the estimated cost is estimated in the order of 5 to 6 million dollars. By comparison, it is understood that a

recent estimate to extend a line from Prince Rupert to the nearby village of Kitkatla, was approximately 10 million dollars. The distance is about 72 km but includes submarine crossings.

Should the Hartley Bay community qualify for the REA program grants, it may be possible to reduce the capital cost to the village for a grid tie-in, by 3/4 to 1 million dollars, leaving a net cost of at least 4 to 5 million dollars. By comparison, the estimated cost of 2.7 million dollars for a hydro plant installation would appear to be a more attractive option for the village of Hartley Bay.

6.0 EVALUATION OF ENERGY ECONOMICS

6.1 GENERAL CONSIDERATIONS

The general approach to the economic evaluation for this study has been to develop a system which would yield a comparison and ranking on the basis of cost effectiveness of the various policy, generation and conservation alternatives found to be technically feasible at Hartley Bay. At the same time, the evaluation methodology has been designed so that it will provide a conceptual framework and analysis tool for evaluating similar alternatives at other isolated native Indian communities in British Columbia.

To this end, it has been necessary to address the following considerations:

- existing energy consumption and use patterns at Hartley Bay;
- "normal" energy consumption and use patterns for a community like Hartley Bay;
- energy costs associated with each;
- projections of population, household formation and other demographic factors which will influence future consumption patterns;
- projections of energy costs.

With these parameters defined, a forecast of future energy consumption and costs for Hartley Bay can be developed assuming that petroleum fuels remain as the primary source of energy in the community.

Alternatives for reducing or removing reliance on oil will then be evaluated as incremental cost increases or decreases to the existing system. Finally, those alternatives indicating positive benefits would be ranked according to the criterion of cost-effectiveness.

Definition of the existing energy use system at Hartley Bay presents a number of difficulties in that the necessary historical data is incomplete and various policies and practices tend to distort the consumption patterns away from that which might be considered the "norm". In addition, a major component of any economic evaluation of energy alternatives is the forecasting of future patterns. To the extent that the starting point cannot be determined, forecasting becomes extremely difficult.

In order to establish a reasonable existing base case on which forecasts can be developed and to which alternative cases can be compared, a model has been constructed to incorporate a combination of actual data from Hartley Bay as well as statistics available from energy industry sources. The result is a "base case" which might be characterized as describing what ought to be the energy consumption patterns for a community having the same size and general structure as Hartley Bay.

Implicit in this base case is the assumption that pricing of energy is equivalent in the model community to that in the rest of the province. It is also implied that for forecasting purposes, the supply of energy is unlimited and consumption becomes a function of demand and price alone. The advantage of making these assumptions is that the base case can be readily adjusted for application to other

communities simply by substituting variables for size and structure.

A number of other assumptions have been required for the development of the energy consumption model and these are specified in Section 6.3 which describes the model in detail.

Regarding the development of a "normal" base case in addition to the actual case of what is happening at Hartley Bay, a comparison of the two can serve as a starting point for analyzing where immediate changes can be made for improving the energy efficiency of the village. It is likely that the chief causes of differences between these two cases are the pricing policies discussed in Section 6.2, administration of the energy supply system, and consumer practices. To the extent that these can be changed at nominal cost, they become obvious candidates for immediate attention.

6.2 POLICY CONSIDERATIONS

6.2.1 Electrical Supply Policy

DIAND offers assistance to a number of Indian Reserves to supply basic services such as water, housing, and electrical power.

At the present time about 17 remote Reserves have been provided with an electrical power system. Two of these are hydro-based while the rest are diesel. DIAND is currently promoting the connection of as many Reserves as possible to the provincial grid, or alternatively, is seeking to have B.C. Hydro assume responsibility for the existing and future diesel generation systems.

The existing electrical systems provided by DIAND are intended to operate under the following guidelines:

- residents are charged a flat rate based on agreed-to average electrical consumption of 700-800 kWh/month;
- the flat rate is based on the B.C. Hydro residential energy cost schedule for a 700 kWh/month consumption;
- electrical use in excess of this monthly consumption is (supposed to be) borne by the user at full cost.

The intent of the DIAND power policy is to provide a basic service to Reserve residents at a cost (to them) which is comparable to B.C. Hydro's residential customers. Reserves are required to make other provisions to meet their space and hot water heating needs.

The full cost of diesel generated energy is calculated by DIAND to be about 30¢/kWh (based on a full accounting of capital carrying charges, operation and maintenance, and fuel costs). As a consequence, DIAND is subsidizing, directly or indirectly, both the incremental cost on the first 700 kWh and also the full cost of any excess energy used. This situation encourages wasteful practices, and the unauthorized use of electricity for hot water and space heating purposes, a practice that results in the very inefficient use of diesel oil (compared to direct oil heating).

6.2.2 Housing Policy

DIAND annually provides financial assistance to Reserve residents for housing and as of 1983 has stipulated that new construction standards are to meet specific energy

conservation criteria. The thermal insulation effectiveness of the present houses depends generally on the year of construction; for houses constructed in the 1950's and 1960's, low energy costs provided little incentive to insulate. Within limits, DIAND's present policy is to provide new housing in numbers sufficient to meet population growth, reduce over-crowding in existing houses, and allow for the demolition of older housing.

Gradual replacement of poorly insulated housing stock and the installation of new energy efficient housing will affect the future heating needs for the community and steadily lower the average heat consumption.

6.2.3 Energy Pricing

Hartley Bay residents generally pay market prices for heating oil and propane supplies, while electricity supplies are subsidized. All forms of energy currently available to the village are relatively expensive, given the transportation costs of oil and propane supplies and the conversion losses involved in diesel powered electric generation.

The de facto policy of DIAND has been to provide sufficient electrical power to the village such that each residence has available approximately 700 kWh per month, which is considered the average demand for a household not using electricity for hot water or space heating. This level of power is presently supplied at a price of $25 per month, which was intended to approximate the average price paid by B.C. Hydro customers in the province. (The B.C. Hydro price, however, is now closer to $35 for 700 kWh, or 5¢ per kWh.)

Electrical use beyond the first 700 kWh is to be charged at the full cost of production which, at a minimum, would be the marginal cost of the additional diesel fuel used to produce additional power. At 46¢ per liter for diesel and a yield of 3.3 kWh per liter, the cost of an additional kWh comes to 14¢. Certainly, a price of this magnitude would discourage excess power consumption, since oil energy is available at less than half this price.

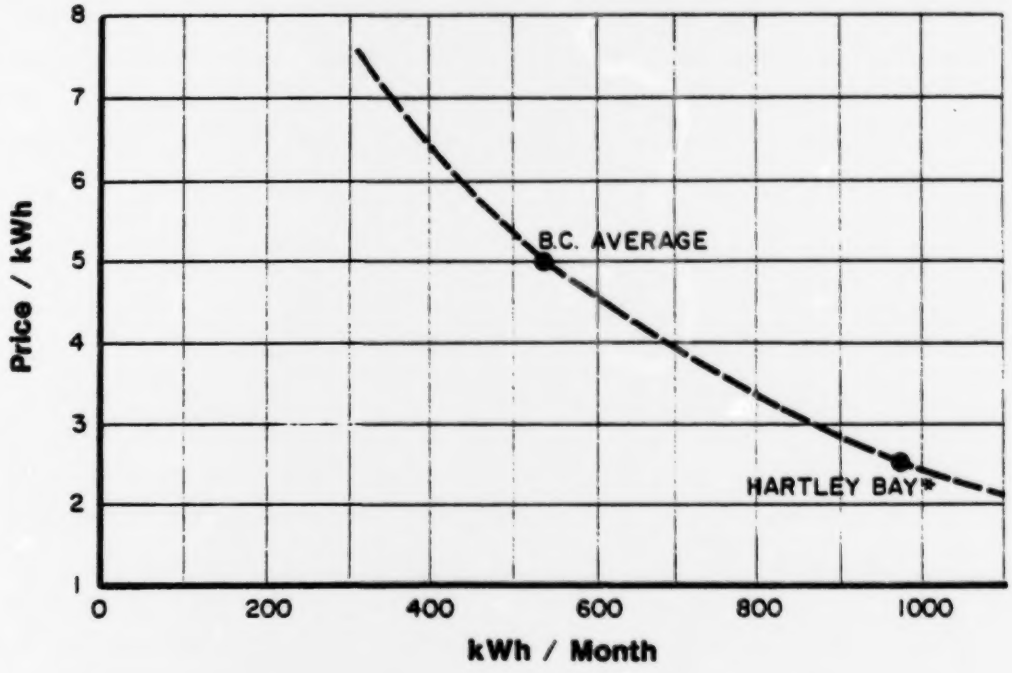
The pricing policy described above should in general elicit a consumer response of using exactly 700 kWh per month. It is not rational to use more since the unit cost is far greater than available alternatives, nor is it rational to use less because below this level the alternatives are all more expensive.

Failure to implement the pricing policy noted above, specifically by having no means to identify electrical demand over the 700 kWh level due to lack of metering, results in the removal of economic controls on consumption. In effect, electrical energy used over and above 700 kWh is free to the consumer, the only control being through informal regulation of what appliances are allowed into the village. With this system, it is perfectly rational for the consumer to maximize the consumption of electrical energy since even the use of clothes dryers (for example) as space heat sources, is less costly to the consumer than the alternatives. Furthermore, since even the nominal $25 per household charge for electricity is often not collected, the consumer is doubly encouraged to consume electricity. As a result, the only factors serving to moderate electric demand are the cost of more appliances, a sense of support for the common good and perhaps conscience.

It is therefore not surprising to discover that the average household in Hartley Bay consumes approximately 990 kWh per month, and yet, are given the stock of appliances found in Hartley Bay, consumption should be only about 540 kWh per month. These figures suggest that Hartley Bay residents consume roughly 80 percent more electrical energy than the provincial average. This difference is probably almost entirely due to the pricing mechanism in place which encourages consumers to use electrical space heating and water heating.

Figure 6-1 illustrates how electric demand changes with price based on the actual demand at Hartley Bay and the provincial average demand. The exact slope and shape of the curve in Figure 6-1 cannot be specified given the data available; however, clearly, if the prices increased in Hartley Bay, there would be substitution of other fuels such that demand would decrease in some proportion. In the range between 2.5¢ per kWh and 5¢ per kWh, at least, the indicated rate of substitution suggests that for every one cent increase in price, demand falls about 180 kWh, or alternatively, a 100 percent increase in price results in a 45 percent decrease in demand. If electricity were priced at its true cost of production, demand would probably be reduced to substantially lower levels, possibly even disappearing altogether.

A further implication of the pricing policies currently in place is that the results run counter to the objectives of the federal government's "off-oil" policies in that the unrealistically low prices for electricity encourage consumption while diesel electric generation is the least efficient of the available energy resource options available.



*Hartley Bay price : $25 ÷ 990 kWh = $0.025/kWh

FIG.6-1

OFF-OIL ENERGY GENERATION & CONSERVATION

OBSERVED ELECTRICAL CONSUMPTION AS A FUNCTION OF PRICE

AGRES

6.3 COMPUTER MODELLING

In order to analyze the energy use profile of Hartley Bay in detail and to evaluate off-oil or oil reduction alternatives, Acres has adapted in-house computer software for this study. It has also been the intent of the computer modelling exercise that the system be readily applicable as an analytical tool to other remote native communities in B. C.

Three separate modules of the computer program have been established to handle data inputs on Energy consumption, Demographics and Financial evaluation. For this reason, it has been termed the EDF Computer Program, the structure of which is illustrated in Figure 6-2.

The energy consumption module, which has been used to describe the energy demand at Hartley Bay and to distribute it to appropriate end-uses, has been discussed in Section 3.2 on demand analysis. This module specifies a "normal" base case; that is, it relies on consumption coefficients developed from utility company statistics and engineering considerations. Key variables in this module are: specification of housing stock, population, fuel prices, degree-days and specification of non-residential buildings.

Based on site investigations at Hartley Bay, values for these variables have been applied to describe that village's energy consumption. The same data for another village could readily be used by the model to describe the energy system there.

The second component of the model is the demographic module. This module takes population growth estimates and particulars of housing replacement policies to provide projections of population and housing stock. Section 3.4 discusses the output from this module for the Hartley Bay case.

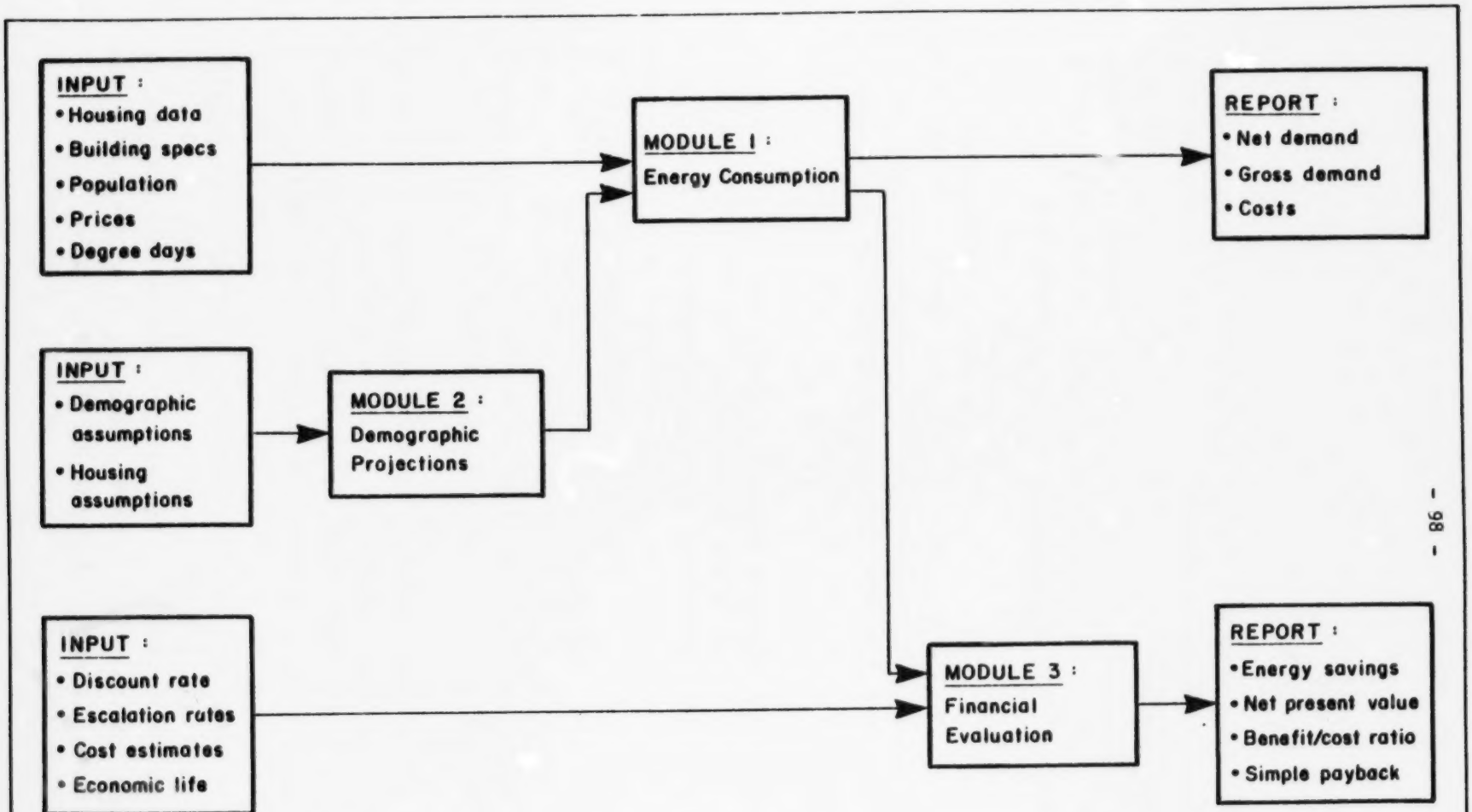


FIG.6-2

OFF-OIL ENERGY GENERATION & CONSERVATION

EDF COMPUTER PROGRAM
FLOW DIAGRAM

ACRES

The combined output of the energy consumption module and the demographic module is utilized by the financial evaluation module. In addition, this module must be provided with assumed discount and escalation rates as well as capital and operating cost estimates for the energy conservation or generation alternatives to be considered. Energy savings are calculated by reference to the energy consumption module which is utilized to develop "before" and "after" scenarios for the particular alternative under study. The financial evaluation module rates the feasible alternatives on the basis of three separate investment criteria: net present value, benefit/cost ratio, and simple payback. Each of these is defined as follows:

- Net Present Value: The summed current equivalents of the value of future net savings or income (in this case, oil purchases avoided, less the incremental operating costs of the alternative) minus the current equivalent of the initial investment. Each future amount is discounted at a rate which represents the time value of money. It represents the economic gain derived from a project over and above returns on invested capital in the magnitude of the discount rate.

- Benefit/Cost Ratio: A profitability index used for capital expenditure projects, which is given by the ratio of the present value of net savings or income divided by the present value of the initial investment. It can be interpreted as indicating the amount of financial return to each dollar invested. Projects for which this ratio exceeds 1.0 show a positive return and are deemed acceptable.

- Simple Payback: A measure of the time required for the expected cash inflows generated by the project to equal the original cash outlay. It indicates when the investment is recouped and how long the invested funds are exposed to the risks of uncertainty.

In Section 7.0 following, these investment criteria are used in evaluating four oil reduction projects considered potentially beneficial for Hartley Bay.

7.0 EVALUATION OF SELECTED PROGRAMS AT HARTLEY BAY

7.1 INTRODUCTION

Four opportunities for reducing or eliminating oil consumption at Hartley Bay, identified in the course of this study, have been selected for further analysis. Each has potentially attractive economic benefits, and merits quantification of potential oil savings.

These analyses demonstrate some of the applications of the EDF computer program established for the purposes of the study and detailed in Section 6.0. The program is used to arrive at the economic benefits of each option.

The financial analysis of these options adheres to the recommended procedures of the "Implementation Manual for Off-Oil and Retrofit Programs (1982)" issued by Energy, Mines and Resources Canada. Specifically, the analysis relies upon present value methods for evaluating the future benefits of oil reductions and includes application of suggested "crown premiums" on the unit prices of oil saved. These crown premiums are utilized on the basis that off-oil or retrofit programs in native communities are likely, either directly or indirectly, to be federal projects. This being so, the true cost of oil to the Canadian economy is the price of imported oil, since this is the marginal price and is in fact the oil which would be displaced by oil reduction measures. At the same time, the analysis includes market prices for oil to indicate the direct financial savings available to Hartley Bay as a separate entity.

All values in the subsequent analysis are stated in mid-1983 Canadian dollars. There is no allowance for inflation in the

calculations; thus, the assumed discount and price escalation rates are "real" rates, not influenced by changing general price levels.

All options are evaluated with a discount rate of 5 percent. This value is rather high for a "real" discount rate, given historical levels of between 3 and 4 percent. However, given current relatively high spreads between inflation and lending rates (say 6 percent versus 11.5 percent), the 5 percent rate is considered appropriate for this analysis.

Escalation rates have only been used in the analysis of the hydro-electric alternative (Section 7.4). The other options are relatively short term and escalations would not change them significantly. In the hydro projections, the following escalation rates are incorporated:

Oil Prices: 0% (real) to 1990
1% from 1991 to 2000
2% after 2000

Operations and Maintenance: 3% over economic life

Crown premiums utilized here are based on actual prices at Hartley Bay and are calculated as follows:

$$\text{Heating Oil:} \quad \frac{0.38 + 0.092}{0.38} = 1.24$$

$$\text{Diesel Oil:} \quad \frac{0.46 + 0.092}{0.46} = 1.2$$

7.2 ALTERNATIVE 1 - APPROPRIATE PRICING AND INCENTIVES

As noted in the discussion of energy pricing policies in native communities (Section 6.0) and the analysis of consumption patterns at Hartley Bay (Section 3.4), there is a clear tendency (and indeed an incentive) to maximize electrical power consumption while minimizing heating oil consumption. Such behavior maximizes the benefit to the individual consumer. However, from a broader perspective, this distorted demand pattern introduces unnecessary inefficiencies and is detrimental to the common good.

Specifically, there has been a substitution of an energy process which yields from 50-55 percent of the gross energy (heating oil combustion) by a process which yields only about 30 percent of the fuel energy content (electric generation). In addition, the diesel fuel is more expensive than heating oil. As a result, the overall village energy conversion ratio works out to about 40.7 percent.

However, if more efficient heating oil combustion were used for all electrical space heating, water heating and cooking, the overall energy conversion has been calculated to be 46.2 percent. Therefore, merely by shifting these end uses to the appropriate (i.e. more efficient) energy resource, an immediate gain in efficiency is available. The economic impact of this shift is significant.

Assuming total consumption remains at current levels (7,792 GJ net; 19,151 GJ gross), a move to a conversion efficiency of 46.2 percent would indicate a reduction in gross demand of 2,285 GJ per year as shown in Table 7-1.

Since the displaced gross energy requirement is diesel oil, the annual dollar savings are $26,940, based on a current price of $0.46/L at Hartley Bay.

The direct costs of achieving these savings are primarily associated with purchasing and installing the appropriate appliances and equipment. (namely, some 30 oil-burning water heaters and 4 kitchen ranges) to replace electric-powered ones. The assumed direct costs are shown in Table 7-1.

There would be no need to purchase oil burning space heaters since these already exist. It would be necessary, however, to suspend the use of all electric space heaters.

Assuming a conservative zero percent real increase in oil prices and an economic life of the program of only 10 years, the present value of the program is substantial, as shown in Table 7-1.

Few investments offer a potential return of between $12 and $14 for each dollar invested. Still, it is recognized that implementation of this program would raise a number of difficulties, especially with respect to the distribution of these benefits and who covers the costs. Nevertheless, whether they accrue to the community only or the Canadian economy in general, there are over $200,000 of benefits available by achieving these efficiency increases.

7.3 ALTERNATIVE 2 - INSULATION

There appear to be a number of opportunities for reducing oil consumption through the retrofit of better insulation on existing homes in Hartley Bay. Type X homes are the most serious source of heat loss in the village but the expected

TABLE 7-1

ALTERNATIVE 1 - APPROPRIATE PRICING AND INCENTIVES

Assumptions:

Capital Cost: 30 hot-water heaters	@ $500	$15,000
4 ranges	@ $650	2,600
		$17,600
Annual cost		-
Estimated life		10 years
Real discount rate		5%
Oil price escalation		Flat

Value of Annual Savings:

$$\text{Reduction in gross demand} = 19{,}151\ \text{GJ} - \frac{7{,}792\ \text{GJ}}{0.462}$$

$$= 2{,}285\ \text{GJ}$$

Annual savings = 2,285 GJ x $11.79/GJ

= $26,940

(based on price of $0.46/L at Hartley Bay)

Present Value of Program:

	Market Prices	World Prices
Present Value of Savings	$208,000	$249,628
Present Value of Initial Cost	(17,600)	(17,600)
Net Present Value	$190,400	$232,028
Benefit/Cost Ratio	11.8	14.2
Simple Payback	7.8 months	6.5 months

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life of these is quite limited in that they will be replaced over the next two years.

Type A homes are the most numerous in the village and are also poorly insulated. Since these structures tend not to have any floor insulation at all, floor losses are extremely high at 34.5 GJ (net) per house per year. (This compares with 8 GJ for Type B houses.) Floor insulation therefore becomes an obvious candidate for retrofit in Hartley Bay.

As an example of the utility of the energy consumption model, a computer print-out is provided in Appendix B3 that indicates the value of floor insulation in Type A houses. The formula in the model, which calculates the floor losses, has been altered such that the loss factor for Type A houses is set at 1.5 times the loss factor for Type B houses. This is done on the assumption that retrofit of R12 insulation in the Type A houses will not be as effective as the original installation of R12 in the Type B houses, due to the poorer construction of the former, the difficulties of achieving adequate vapour barrier properties, and the condition of the skirting and crawl space in these homes.

Type A houses are projected for demolition at a rate of 5 per year in 1985 and 1986, and then 2 per year thereafter. As a result, all of the Type A homes will be abandoned by 1998. This schedule indicates a median life on the Type A houses of about 7 years. Using a cost of installed insulation of 60¢/m^2/R (based on B. C. Hydro estimates), the annual value of retrofitting R12 insulation in the floors of Type A homes is calculated as shown in Table 7-2.

The economic value of this option is exceedingly attractive, having a benefit/cost ratio of close to 5 when world oil

TABLE 7-2
ALTERNATIVE 2 - INSULATION
(Insulate Type A floors to 150% of Type B standard)

Assumptions:

Capital cost (31 houses x 60¢/m^2/R x 93 m^2 x R12)	$20,757
Annual cost	-
Estimated life	7 years
Real discount rate	5%
Oil price escalation	Flat

Value of Annual Savings:

Floor Losses	Net GJ	Gross GJ	@ $9.74/GJ
Before (From Appendix B2)	$1,069	$2,138	$20,832
After (From Appendix B3)	357	714	6,955
SAVINGS	$ 712	$1,424	$13,877

Present Value of Program:

	Market Prices	World Prices
Present Value of Savings	$80,297	$99,569
Present Value of Initial Cost	20,757	20,757
Net Present Value	$59,540	$78,812
Benefit/Cost Ratio	3.9	4.8
Simple Payback	1.5 yr.	1.2 yr.

prices are considered. As noted above, insulation of the floor of Type A houses is the most attractive retrofit opportunity but similar gains would be available for other Type A structures such as the old school, church, general store and community hall, provided they are not scheduled for imminent demolition. The energy consumption model can be utilized to check the value of many combinations of insulation retrofit programs, the one presented here being just an example.

Again, the economic analysis presented here is indifferent to who pays for the program and who reaps the benefits. It merely indicates that no matter who does it, the dollar costs and the oil consumed would be less while achieving the same level of comfort. Therefore, no one should be worse off and at least someone (or the country at large) would be better off. The actual distribution of benefits would depend on the arrangements agreed to between DIAND and the Band.

7.4 ALTERNATIVE 3 - DIESEL WASTE HEAT RECOVERY

As noted in Section 4.4, most of the energy content of the diesel fuel used in electrical generation is lost through conversion. However, about 3,015 GJ of the wasted energy from a 150-KW diesel generator are recoverable. Since the generation of this waste heat will not coincide in timing with the demand for heat, it is estimated that only about 70 percent, or 2,110 GJ, can be effectively used. This 2,100 GJ of net space heating energy can directly replace an equivalent amount of space heating energy derived from heating oil. Since the converstion efficiency on the oil burning is assumed to be 50 percent, 4,220 GJ of gross energy purchases can be avoided.

The estimated installed cost of the heat recovery system is $100,000 and the annual operations and maintenance costs are estimated at $3,000. The project economic life used here is 15 years. This is longer than the expected life of the existing diesel unit but assuming they are replaced as required, the economics of the waste heat recovery system are unaffected. The calculations in Table 7-3 indicate the annual value of waste heating recovery.

The benefit/cost ratios for this alternative are about equal to those for the insulation retrofit discussed in Section 7.3. Therefore, each of these projects returns up to $5 for each dollar invested. The payback period is longer for this project but the benefits are expected to last over a longer period of time.

7.5 ALTERNATIVE 4 - HYDRO-ELECTRIC GENERATION

Construction and operation of a small hydro-electric generating station on Hawkesbury Island presents a number of complications in the economic analysis not present in the analysis of the relatively short term programs discussed in the previous sections. Hydro-electric generation represents a "complete" off-oil alternative in that the energy produced by the plant can displace all oil consumption in Hartley Bay for space heating, hot water heating, cooking, lights and appliance end-uses.

Also, the hydro alternative must be compared to the next best energy supply alternative to isolate the incremental benefits of the project. For this analysis, the next best alternative is taken as the use of electricity for lights and appliances only, and of heating oil or propane for all other purposes. In other words, hydro is not evaluated against the present inefficient system.

Economic life for the hydro option is assumed to be 50 years. The oil-supplied energy displaced by hydro is based on the projected energy requirements indicated in Figure 3-1 (Section 3.4.4). As discussed there, the projections are based on a catch-up during the years to 1990 from current, relatively suppressed demand levels of about 7,800 GJ per year to 10,500 GJ in 1989. Thereafter, expected demand growth is a modest 0.83 percent per annum. For the subsequent 30 years, annual growth of 1 percent if assumed.

Oil escalation rates over this period have been assumed as indicated in Table 7-4.

The weighted average price for energy purchases taken from the energy consumption model is $10.30 per GJ based on market prices in Hartley Bay. Application of the crown premium gives a price of $12.36 per GJ.

Projected energy demand and the gross energy requirements displaced by the hydro option are provided in Table 7-5. The displaced energy (that is, the oil savings) is based on an overall conversion efficiency of 46 percent, which is higher than that currently being achieved in Hartley Bay.

In addition to the oil purchases avoided as a result of the hydro option, the costs of operation, maintenance and periodic replacement or overhaul of the diesel system are avoided. These costs are estimated as shown in Table 7-4.

However, even if hydro is installed, one of the existing 150 kW generating units would be retained in operating condition for emergency standby. It is assumed that this unit will require an overhaul each 10 years and replacement at 25 years for a cost of $50,000.

TABLE 7-3
ALTERNATIVE 3 - DIESEL WASTE HEAT RECOVERY

Assumptions:

Capital cost	$100,000
Annual cost	$3,000
Estimated life	15 years
Real discount rate	5%
Oil price escalation	Flat

Value of Annual Savings:

	Market Prices	World Prices
4,220 GJ	$41,103	$50,968
Operation & Maintenance Expense	3,000	3,000
Net Savings	$38,103	$47,968

Present Value of Program:

	Market Prices	World Prices
Present Value of Savings	$395,496	$497,891
Present Value of Initial Investment	100,000	100,000
Net Present Value	$295,496	$397,891
Benefit/Cost Ratio	3.9	5.0
Simple Pay Back	2.6 yr.	2.1 yr.

TABLE 7-4
ALTERNATIVE 4 - HYDRO-ELECTRIC GENERATION

Assumptions:

Capital cost	$2,600,000
Annual cost - Initially 2% of capital cost: (escalating at 3% per annum)	$52,000
Estimated life	50 years
Real discount rate	5%
Oil price escalation	0% to 1990
	1% fro 1990 to 2003
	2% thereafter

Value of Net Annual Savings:

Gross energy displaced	Per Table 7-5
Market price	$10.30/GJ
World price	$12.36/GJ
Diesel plant costs avoided:	
Replacement (2 x 150 kW units)	$100,000
Life	10 years
Annual O & M (3% of capital cost)	$3,000
Overhaul Cost	$20,000
Overhaul Frequency	5 years
Escalation: - O & M	3%
- Overhaul	3%
- Replacement	3%
Diesel plant stand-by costs:	
Replacement (1 x 150 kW unit)	$50,000
Life	25 years
Annual O & M	negligible
Overhaul cost	$20,000
Overhaul Frequency	10 years
Escalation: - O & M	3%
- Overhaul	3%
- Replacement	3%

Present Value (PV) of Program:

	Market Prices	World Prices
Present Value of Savings	$5,662,480	$6,795,680
Present Value of Diesel Plant Avoided	461,800	461,800
Less: PV of O & M (2% of Cap. Cost)	($ 1,634,000)	($1,634,000)
PV of Diesel Standby	(88,700)	(88,700)
PV of Net Savings	$ 4,401,580	$5,534,780
PV of Initial Investment (from Acres, 1982)	2,600,000	2,600,000
Net Present Value	$1,801,580	$2,934,780
Benefit/Cost Ratio	1.7	2.1
Simple Payback	14.5 yr.	11.5 yr.

TABLE 7-5

OIL SAVINGS ON HYDRO-ELECTRIC ALTERNATIVE

Year	Net Energy* Demand (GJ)	Gross Energy** Displaced (GJ)	Annual Growth (%)
1983	7,800	17,000	
1984	8,300	18,000	
1985	9,000	19,600	5.0
1986	9,500	20,700	
1987	10,000	22,200	
1988	10,300	22,400	
1989	10,500	22,800	
1990	10,600	23,000	
1991	10,600	23,000	
1992	10,700	23,300	
1993	10,800	23,500	
1994	10,900	23,700	
1995	11,000	23,900	
1996	11,100	24,100	0.83
1997	11,300	24,600	
1998	11,400	24,800	
1999	11,400	24,800	
2000	11,500	25,000	
2001	11,600	25,200	
2002	11,700	25,400	
2003	11,800	25,600	
-	-		
-	-		
-	-		1.0
2033	16,100	35,000	

* Based on "expected case" as discussed in Section 3.4.4.

** Assumes 46% overall energy conversion efficiency.

The economic value of the hydro option is also indicated in Table 7-4.

As can be seen from the foregoing analysis, the hydro option also has substantial economic benefits (i.e. close to $3 million when world prices are considered). Obviously, the hydro option also has a far greater impact on the objective of reducing oil than any of the other alternatives considered here. The initial costs are certainly greater but then so are the potential benefits.

If it is intended to pursue the hydro option, it should be noted that the options of exchanging the electric water heaters and of installing the diesel generator heat recovery system should not be pursued. These latter options run counter to maximizing the hydro option, and vice versa.

7.6 ENVIRONMENTAL AND SOCIOECONOMIC CONSIDERATIONS

7.6.1 Environmental Impacts

Potential environmental impacts from energy generation can be classified as follows (Acres, 1982):

- reduction of animal/fish habitat
- reduction of sensitive/important vegetation
- land use competition
- air emissions
- noise
- water quality and use
- visual impact
- electromagnetic field interferences
- waste disposal

Impacts of a diesel generating system such as that in use at Hartley Bay can be summarized to provide a baseline for comparison with other systems. The system is housed in a modest building adjacent to the community, thus having little impact on wildlife habitats or land requirements. Air emissions are produced as a result of the combustion process, and noise is emitted to the surroundings. Water use is minimal, as the cooling system is sealed and rarely drained. Visual impact is limited to the area of the protective structure - the stack plume, fuel storage, and the building itself (separate from the distribution cables which would exist with any production methods). Electromagnetic field interferences are minimal unless a defect exists in the generating system. Waste disposal is primarily limited to waste oil, parts boxes and cartons, and scrap parts.

Of the four alternative energy programs discussed in Sections 7.1 to 7.5, only the hydro-electric plant (Alternative 4) would have significantly different environmental impacts from the status quo. A hydro-electric development would alter streamflow conditions as well as reduce vegetation and habitat through reservoir flooding and clearing for the transmission line.

Two main sites were referred to in Section 5.2.2 as meeting Hartley Bay's requirements for a hydro-electric development. As discussed in the Acres (January 1983) report, for the Hawkesbury Island site, no environmental difficulties are foreseen, beyond interference with riparian users during the course of construction. The area should, however, be surveyed for rare and endangered species. For the site located between the upper and lower lakes on the Hartley Bay River, the fish habitat should be assessed. The lower section of the Hartley River between the lower lake and Douglas Channel

is a known salmon spawning area. Local opinion suggests that salmon do not enter the river above the lower lake but this should be confirmed. Upstream developments on the Hartley River are not expected to affect spawning conditions on the lower river, although it may be necessary to determine the minimum water release during the spawning periods. The effects of regulated river flow on the fish resident in the lakes and river should be examined. In addition, the area should be surveyed for raptors or other protected species, and to report on any effects on riparian users, if any.

7.6.2 Socioeconomic Considerations

With respect to socioeconomic considerations, a hydro-electric power development could have significant impacts on Hartley Bay compared with the other energy conservation/ generation options discussed in this report. The most significant potential impacts are:

- employment opportunities during construction; and,
- increased attractiveness of the community as a population centre, due to availability of surplus power.

Hartley Bay could possibly develop as a population centre if the hydro-electric scheme were installed. The abundant supply of electricity would make the living conditions more attractive and could encourage establishment of local industries. As an example, since the Klemtu hydro-electric plant began operation, it has been observed that Kitasoo I.R.1 has attracted population from the surrounding areas.

The hydro-electric system (Alternative 4) could also provide a number of employment opportunities during construction.

The plant would be capable of long periods of maintenance-free operation; ideally maintenance should only be necessary at monthly intervals to take care of lubrication and minor adjustments. Such routine maintenance could be handled by a diesel or auto mechanic provided that additional training is given.

The energy conservation/generation options other than hydro-electric would have little or no long-term socio-economic impact on Hartley Bay. Implementation of some or all of the programs would provide better value for the dollars spent on energy, but none would significantly increase the quantity of energy available in the community. It should be noted that the "better-value-for-the-price" interpretation ignores the existing policies discussed in Section 6.2. In fact, a move away from electric power use would shift the burden of cost from DIAND to the Hartley Bay consumer. Thus any option other than hydro-electric power would have adverse economic impacts on the individual user, although from a much broader perspective the economic impact would be considered beneficial.

No major inconvenience to the user is anticipated from any of the four programs proposed, in Section 7.0 herein, for Hartley Bay. (In contrast, wholesale conversion to coal furnaces or wood stoves, for example, would probably be considered unacceptable to the users.) Some short-term inconvenience would be experienced during installation of insulation (Alternative 2) and while changing appliances during the implementation of Alternatives 1 and 4.

None of the other alternative programs would provide significant job opportunities for Hartley Bay residents, although systems such as diesel waste heat recovery would

require a modicum of maintenance by the diesel mechanic. Certain other options such as use of coal or propane would require an improved transportation and distribution system, which would perhaps employ Hartley Bay residents. Development of a wood cutting operation, discussed in Section 5.4.2 as an extension to the sawmill, would also involve local residents.

8.0 SUMMARY

8.1 DATA COLLECTION AND HARTLEY BAY

In this study, energy conservation measures and alternative energy sources have been identified, which may be economically viable and applicable to remote communities, depending on their individual circumstances.

However, to ensure that the study was based on practical considerations at such remote locations, the Indian community at Hartley Bay was selected as a typical example. This village, with a population of about 234, is heavily dependent upon diesel and heating oil for power generation and space heating. The Acres team visited the village for purposes of inventory and data collection in mid-June 1983.

The study objectives indicated a need for specific information in the following areas:

- the pattern of energy consumption in the village including residential space heating and appliances, community and commercial buildings, and industrial use (if any);
- energy sources and conversion modes;
- assessment of site-specific factors which may affect current data as well as future energy options;
- plans for future community development;
- any other relevant factors.

Reasonably accurate records of oil deliveries to the village were available for the last two years. No such records were

available for other forms of gross energy input such as propane and wood. These were estimated based on opinions expressed in response to the Acres team enquiries. No metering records were available to give any indication of electrical power output, consumption distribution or period load demand characteristics. To the extent necessary, these were assessed based on typical generator performance, the implications of the inventory data, and consumption data obtained from B.C. Hydro.

These data limitations are no doubt typical of most remote communities.

8.2 SPACE HEATING AND ENERGY CONSERVATION

Notwithstanding the data limitations, in the absence of any energy-consuming industry of Hartley Bay, it was apparent that space heating accounts for the major use of energy. This is followed by residential appliances. In fact, space heating accounts for approximately 60 per cent of the total energy consumed, and oil provides 90 per cent of the total energy input to the village.

From this it was clear that energy conservation in the area of space heating might play a significant role in reducing oil consumption. Since this is a question of reducing heat losses, it was therefore necessary to classify the housing stock in 4 types according to standard of construction relating to insulation and weather proofing. For each type, heat losses were estimated for ceilings, floors, walls, windows and doors, and general infiltration, using standard thermal data applied to the observed conditions. The classification is described in Section 3.0.

Based on estimates subsequently generated, opportunities for improved energy management were identified. In addition, diesel generator waste heat recovery and other possibilities were examined as described in Section 4.0.

8.3 OTHER ENERGY SOURCES

The use of other energy sources as alternatives to oil very much depends on the availability of such sources in the proximity of the remote community. It also depends on the viability of installing and operating a variety of equipment for harnessing and distribution. A total of 10 potential alternative energy resource options were examined, as described in Section 5.0.

In the case of Hartley Bay, available records were examined to determine the availability of any alternative energy sources. An opportunity for developing a small hydro electric scheme was indentified by Acres in their report "Hartley Bay Indian Reserve No. 4 Hydroelectric Pre-investment Study" dated January, 1983. The economic viability of this possibility is further discussed in Section 7.5. Greater use of wood, developed on a community basis, also appears to be a possibility for space heating.

8.4 CONSUMPTION PATTERN

In order to determine the impact and economic feasibility of any off-oil option that is to be considered, it is necessary to establish current consumption patterns and trends. It is also necessary to consider the various means for conversion of the gross energy input into net useful end use. The difference results from the number and efficiency of conversions.

Conversion efficiency may range from 30 percent in the case of diesel oil consumed in residential space heating via electrical generation, to 65 percent in the case of propane used in kitchen ranges. Conversion efficiency for the direct use of heating oil, which is also cheaper than diesel oil, is about 50 percent. In the absence of specific data, a number of analytical steps based on field observations were used as described in Section 3.0. The final step, in the development of this demand analysis, is to apply demographic projections to current data to arrive at energy trends.

8.5 COMPUTER PROGRAM

In order to manipulate the data, a computer program was established consisting of three modules.

The first program module develops a gross energy consumption and cost estimates for each sector and end-use. It is based on local degree-days, existing building stock, range and type of appliances typifying local lifestyle, and current prices for the various forms of fuel. By examining total energy costs in this module, the most likely opportunities for significant conservation and savings are identified. The module will also show the impact resulting from changes in input data, such as changes in the number and standard of housing units over time, as well as changes in conversion efficiency and pricing.

Optimum conversion is assumed in this consumption model. By comparing the gross energy demand results of the model with the records obtained from the field, a picture of energy use in the community emerges. For example, it is possible to see whether the community is making the best use of its energy input, and how its lifestyle (as measured by total energy

consumption per capita or per household) compares to that in non-remote areas.

The second module produces demographic projections of population and changes in the housing stock. By inputting into module 1 the results obtained from module 2, it is possible to obtain energy consumption trends for the community over an extended period of time.

The third program module carries out standard economic projections for the proposed option and compares it to similar projections for the diesel generator supply base case, given economic life, and real rates for price escalation, interest and discount. The difference between the two projections represents a stream of savings (if positive) which is reduced to a net present value. The benefit/cost ratio and simple pay back period are also determined.

Some lack of data must be expected in remote communities, although annual oil deliveries and their disposition is obviously a prerequisite. Notwithstanding, it will be seen that this analytical methodology and computer program constitute powerful tools for the analysis and justification of off-oil investment opportunities.

8.6 FINDINGS AT HARTLEY BAY

At Hartley Bay, a number of interesting findings have emerged.

- The Hartley Bay community with its present village population of 234 spends approximately $190,000 per annum ($800 per person) on all forms of oil.

- The corresponding annual offshore oil value (cost to the nation) is estimated to be approximately $230,000 per annum.

- Housing in the community varies widely from the oldest Type X to the most recent Type B. The Type X houses, although small (average 71 m^2), are wasteful of energy. However, under DIAND's continued policy of housing stock replacement, the Type X houses should be eliminated by 1985.

- Type A houses, albeit larger (average 93 m^2) than Type X, are somewhat more energy-efficient. However, due to little or no floor insulation (no basement) and poor weather protection, opportunities exist for significant energy savings by reducing losses through the floor and infiltration generally. In this respect alone, it is felt that the community should benefit from an educational program of energy conservation and management.

- The Type B houses (average 98 m^2) show significant improvement in energy efficiency, since they require only 65 percent of the space heating energy required for Type A.

- The Hartley Bay population is projected to expand at around 1.5 percent per annum for the next 10 years, and at 1.0 percent thereafter. In spite of this increase, if the program of improved construction house replacement is continued, the theoretical demand for energy remains flat until around the year 2000 and increases gradually thereafter.

- However, a comparison of the field observations with the results obtained from the model of gross energy demand for Hartley Bay indicates that:

  - gross energy consumption in the community is about 80 percent of the model;

  - electricity consumption in the village is about 57 percent higher than it should be;

  - due to the efficiency differential between diesel electric power and direct heat from oil, this means that the net overall energy consumption level is probably about 70 percent of the model. In other words, the community's energy lifestyle is approximately 70 percent of a non-remote community. This may be taken to represent the extent to which the existing energy supply is "capped". Conversely, it indicates the extent by which demand may grow under "uncapped" conditions. It underlines the "energy expectation growth" experienced in other communities, when connected to the general electric grid. A similar result may be expected with the introduction of a small-scale hydro scheme, as demonstrated in Section 7.

- Hartley Bay residents generally pay market prices for heating, oil and propane supplies, which are relatively expensive given transportation costs. They pay a flat rate of $25 per month for electricity, based on 700 kWh. This is equivalent to 3.6¢ per kWh, and is heavily subsidized. The equivalent B.C. Hydro rate is closer to 5¢ per kWh ($35 per month). The marginal cost of diesel power is at least equal to the price of the oil which gives an electric energy cost as high as 14¢ per kWh.

- The flat rate policy encourages residents to take up their full entitlement. In fact, since electricity consumption is not metered, there is an incentive to maximize electrical power consumption at the expense of heating oil. This is evidenced by the presence of a number of (illicit) electric base board heaters and hot water heaters in the village. In effect, power consumed over the 700 kWh per month is free. No doubt this accounts for the high proportion of energy consumed as electricity.

- Given the stock of existing appliances, B.C. Hydro data suggest that the average electric power allowance should be closer to 540 kWh per month, rather than 700 kWh. The actual consumption per household averages 990 kWh per month.

- The yield of useful heat energy through the diesel electric plant is about 40 percent lower than if oil heating is applied directly. Therefore, the flat rate policy and the power allowance run counter to the federal government's policy of reducing oil consumption.

9.0 RECOMMENDATIONS

9.1 REMOTE COMMUNITIES IN GENERAL

Valuable experience has been gained through examining Hartley Bay as a case study. As a result of this experience, it has been possible to establish a relatively simple computer program, which will establish a consumption model based on existing housing and other buildings, project future energy trends, and determine the economic feasibility of various off-oil alternatives.

The next step should be to visit other remote communities to collect the requisite data for each location so that the consumption pattern of the community can be analyzed. At the same time, possible off-oil opportunities can be identified and corresponding economic feasibility similarly determined. Appropriate recommendations can then be made accordingly.

9.2 HARTLEY BAY

A small scale hydro scheme of approximately 500 to 600 kW of firm power could be built near Hartley Bay which would virtually eliminate the growing consumption of approximately 440,000 L of oil per annum (97,000 gals). The scheme would pay for itself in about 14 years, and is the best long term solution to the Hartley Bay energy supply situation.

From recent trends experienced at Klemtu, where a small hydro scheme has been installed, it is anticipated that a similar scheme at Hartley Bay would act as a focus for attracting outlying population and, possibly, local industry.

A policy decision should be taken by DIAND as to whether or not it is the intention to pursue this option.

Other short term possibilities present themselves, which have good pay back periods. These include:

a) Installing a waste heat recovery system on the existing diesel plant. This would save approximately 108,000 L of oil per annum and pay for itself in 2 to 3 years.

b) Change electric hot water heaters to oil heater. Based on the sample, there are an estimated 30 electric hot water heaters in the village. These are heavy power users. If the number is correct, their immediate replacement by direct oil heaters, would pay for themselves in within a year, through oil savings. This would reduce the load on the power plant by approximately 24 percent, and result in net oil savings of about 25,000 L per year.

c) Develop wood as a source of fuel on a community basis.

d) Change the electricity pricing policy to shift the burden of energy supply from the diesel plant to other direct oil use.

It should be emphasized, however, that in general these short term options are mutually exclusive to hydro since they would prevent maximizing the hydro option and vice versa. Moreover, these other options only provide a partial solution to the total energy situation at Hartley Bay. As a result, a real saving in oil is not likely to be realized. Instead, a higher level of consumption can be expected consistent with a rising expectation of energy comfort level.

APPENDIX A1
ALTERNATIVE ENERGY RESOURCE OPTIONS

A1.1 INTRODUCTION

This Appendix provides additional background information on the various forms of off-oil resource options which are more briefly discussed in Section 5.0.

A1.2 HYDRO-ELECTRIC

A unique combination of topographic and climatic features is necessary to provide an economic opportunity for development of hydro-electric energy. Such opportunities in remote communities will be limited.

The energy available at a site is calculated as follows:

$$\text{Power} = C \times e \times Q \times H_{net}$$

where

Power = available power (kilowatts)

C = a constant (approximately 9.81)

e = efficiency of system (approximately 0.80 for small systems)

Q = quantity of water flowing in a given period of time (m^3/s)

H_{net} = "head"; usable difference in elevation between the intake and the point of discharge, minus friction losses in the pipeline.

Thus, for the same power output in kilowatts, there may be either a large quantity of water (Q) with a small elevation difference (H), or a small Q with a large H. It is important that the point of discharge not be too far from the intake; that is, the drop in elevation should take place in as short a distance as possible since the penstock for conveying the water is often the single most costly component of the system. Indeed it is usually the required length of penstock which either "makes" or "breaks" a scheme.

Other features which can enhance a potential project are the occurrence of lakes or developable reservoir areas at the intake elevation of the watershed, necessary to provide storage for use during dry periods. Glaciers and snow packs provide important seasonal storage of water. Proximity of the potential site to the community is important in reducing transmission line costs.

The following features of a potential site are those with the greatest influence on development costs:

- The installed capacity for a particular development determines the size and thus the cost of all components of the project. The capacity will be determined by the economics of system demand and projected load growth consistent with the developable energy and related costs.

- The natural topography of the site influences the costs in that it determines whether the installation will be "high" or "low" head. A high head plant requires much less water for a given capacity thus reducing the size of penstock, intake turbines and powerhouse. High heads may often, but not always, be associated with shorter penstocks. They also permit higher rotational speeds which usually will reduce both turbine and generator costs.

- The hydrology of a site determines the quantity of water available and thus the size of plant which may be installed. The hydrology also sets the daily, seasonal and annual fluctuations in available flow, which determine the amount of storage required and the capacity required for spillway works.

- The length of transmission line required from the plant site to the village can have a significant cost effect on the project. The difficulty of the terrain and requirements for long overhead or submarine spans can also significantly affect the costs.

- The degree of accessibility and difficulty of the terrain have very marked effects on construction costs. Sites which are inaccessible to normal construction equipment or which require extensive use of small equipment or helicopters will be relatively costly to develop.

Environmental impacts must be considered when developing a particular site. These usually are related to destruction or undesirable alteration of fisheries streams or lakes and the flooding of forest, agricultural land and wildlife habitat.

In small hydro development, environmental impacts are likely to be much less pronunced for high head plants than for low head ones, for the following reasons:

- Rivers suitable for high head developments are often not negotiable by fish in the first place.

- Much less water is involved in high head developments, so there is less flooding for storage and habitat disruptions are thus reduced.

A1.3 WIND

Opportunities for exploiting wind energy are highly dependent upon location. Regions experience different wind regimes according to geographic and meteorological conditions. Within a region, local distortion of the natural wind regime can occur due to high relief topographical features. Wind Energy Conversion Systems (WECS) require exposed sites, and site selection requires specific appraisal of prevailing wind conditions at the best apparent locations. For final site selection and WECS design, at least one year of detailed wind data records is required. The west coast of Vancouver Island, the Queen Charlottes and the mainland coast experience the best potential for wind generation, given appropriate exposure conditions (ESL, 1981). At other well-exposed locations within the interior of the province, suitable wind conditions can also be expected.

For WECS designs of more than a few kilowatts a minimum wind speed (cut-in velocity) of around 15 kph is required to commence generation; rated output is achieved at 35 to 55 kph, depending on specific design, and for protection the equipment is stopped (cut-out) at wind speeds of 65 to 80 kph.

Wind variation limits the ability of a WECS to supply power on demand. WECS options to meet specific applications include:

- WECS as a stand alone system
- WECS with battery storage
- WECS with grid interconnection
- WECS with independent back-up power source

With respect to remote community applications, the stand alone option does not meet requirements for dependable power. The second option, involving battery storage, is only practical for serving one or two houses. For a larger community the battery system necessary to provide a number of days storage becomes excessively large, and the consequent cost puts wind generation out of range of competing generation options. The third, grid-interconnection, is not an available option for "remote" communities, by definition. The fourth is left as the principle choice for remote Reserve applications, with diesel generation as the most probable power source.

In practice, the WECS and diesel will operate in parallel. A standby diesel will also be required to meet supply reliability criteria for the electrical system. The diesel generates the bulk of the power and adjusts its output to suit the instantaneous output of the WECS. With a wind-driven AC induction generator, the type most widely used, system stability requirements dictate that the instantaneous output should not exceed about 25 percent of total system load. With this combined arrangement, wind energy acts principally as a fuel saver to reduce the fuel cost component of diesel operation, currently 15 to 20¢/kWh. As such, wind power must compete with this incremental cost rather than the full cost of diesel energy generation. Based on current world oil prices, about 4¢/kWh is added to this incremental cost range.

The majority of WECS in use in the province serve individual residence needs; outputs are typically 2 kW or less. The only one in the size range capable of meeting most remote Reserve needs is the 50-kW DAF Indal Vertical Wind Energy Turbine (VWET) unit at Christopher Point, Vancouver Island,

operated by B.C. Hydro on a demonstration basis for the National Research Council. WECS technology, in sizes above a few kilowatts output, must be regarded as developmental. With completion of B.C. Hydro's extended demonstration program, the experience obtained will be of potential value to remote Reserve applications, as will that of the National Research Council which is currently undertaking a similar program with other 50-kW VWET and also a 220 kW unit.

The estimated installed unit capital cost (current dollars) for the 50-kW DAF Indal unit is $4,500/kW (ESL, 1981). Installation costs at remote locations could increase this figure by 25 percent or more. Transmission line costs, for connecting a high exposure site to a community, will add further to the total. If a WECS annual load factor of 25 percent is also assumed (a reasonable expectation for a correctly sited unit; ESL, 1981)* the above cost factors can be expected to give typical average energy costs in the region of 40¢ to 50¢/kWh.

To indicate the benefits of scale, the installed unit cost ($/kW) of a 200-kW output WECS can be expected to be 10 to 15 percent less than that of the 50 kW machine, resulting in a similarly small reduction in the unit cost of energy (¢/kWh). A substantial reduction in energy cost will be gained primarily by an improvement in annual load factor, i.e. increased annual generation. The potential for such improvement is mainly a function of the wind regime. Remote communities situated close to exposed coastal locations are likely to be the most promising candidates for the application of WECS technology. It is suggested that a wind frequency analysis be undertaken for the more promising

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* The high exposure Christopher Point VWET 50-kW demonstration unit has a predicted design annual load factor of 25 to 30 percent; to date these levels have not been achieved. (Source: B.C. Hydro)

sites, based on available wind station data for the region supplemented by test results from anemometer stations set up at these sites. Combined with a preliminary analysis of candidate commmunity electrical system load behavior, the information would pin-point the most favourable commmunities, defined as those offering high load factor (WECS), high proportion of wind to diesel capacity, and high annual fuel savings potential.

However, in general, it is judged that large wind energy systems for remote Reserve applications are not likely to be competitive, and the technology sufficiently proven for a number of years yet. This does not preclude use of small units of 2 to 5 kW output suitable for individual residences, given favourable site circumstances; the unit cost of these proven horizontal axis machines is much lower.

A1.4 WOOD

Wood waste is used extensively in British Columbia by pulp, paper and sawmill operations, as a means of generating steam for process heating and the cogeneration of electricity. The extent of the provincial wood waste resource, its utilization, and projected surpluses to the year 2000, have been exhaustively examined during the past 10 years. A report by Reid Collins (1978) remains the principal reference source on wood waste use and availability in the province.

The principal observations from earlier studies are:

- Wood-waste surpluses exist at various locations throughout B.C. and much continues to be disposed of by burning and in landfill operations.

- The barging of surplus quantities from forest operations on Vancouver Island and the south coast is done extensively, indicating this to be an economic means of re-distributing surpluses.

- The 1978 delivered price for wood-waste products ranged up to $13/tonne with a corresponding heating value of around 21 GJ/tonne. A significant proportion of the price is for transportation.

- The bulkiness of the product adversely affects the economics of using land-based transport methods over distances exceeding about 80 km.

Woodwaste Electrical Generation

A wood waste fired plant, producing steam for electrical generation or heating purposes, requires a significant investment for wood preparation and handling facilities, and for the large furnaces required. The technology is well developed and proven. The variable properties of the wood-waste product require sophisticated operation and maintenance systems to maintain plant performance. With moisture contents of up to 55 percent, supplementary oil fuel firing (or natural gas, if available) is frequently necessary to sustain combustion at part loads. Such plants are best suited to base load conditions of operation. Realistically, the high capital cost and complexity of a wood-fired electrical generation installation is not appropriate for remote Reserves, considering also current skill levels available, particularly for small scale power generation typically of 500 to 2000 kW output.

Wood Waste - Direct Heating

The delivered cost of wood waste as a fuel source for major users can be as low as $0.50 to $1.00/GJ, a price range clearly attractive in relation to other energy cost options. For remote communities, located on the coast with direct sea/river access, the barging of wood waste appears initially as an attractive option for residential direct heating use. However, wood waste can comprise a single product or a mixture, such as sawdust, chips, bark and off-cuts, and is subject to varying degrees of salt water exposure, moisture content, and dirt content. These factors, particularly product non-uniformity, present difficulties in designing all-purpose handling, storage and reclaim facilities, and combustion equipment. On a residential scale the use of the product for space heating is discounted as impractical.

Cut Wood - Direct Heating

The use of cut wood for stove heating remains the most practical application at remote Reserves. The issues to be addressed to assure a sustainable annual yield have been identified by Crippen (1982). Space heating requirements for typical Type B and Type A residences are 66 to 104 GJ/year respectively. Assuming a combustion efficiency of 50 percent with dry wood and a further 25 percent combustion loss due to moisture content, the typical annual demand for wood is on the order of 22 m^3 (10 cords) and 35 m^3 (16 cords) respectively. The average of all residences might be 30 m^3 (14 cords) per year.

The mean annual increment (MAI) of forest growth in the B.C. coastal region is 5.3 m^3 of solid wood per hectare; the mature wood volume is 612 m^3 per hectare (Crippen, 1982).

This indicates that for a sustained annual yield, i.e. zero depletion of forest resources, the allowable cut is of the order of 5.3 m^3/ha; alternatively, adopting clear cutting practices, the annual yield is 612 m^3/ha. Thus, for the average residence's annual space heating needs, about 6 ha of forest requires working to achieve zero depletion; the corresponding clear cut area would be 0.05 ha/year. The steeply sloped and rugged nature of the terrain typical of B.C. forest conditions makes access and transportation particularly difficult, so that clear cutting is probably the only practical option.

Discussions with the provincial Forest Service indicate that cutting permits can be readily obtained by Reserve residents on application.

Depending on the location of a particular community, forest yields per hectare could be more or less than the mean values indicated above. For many Reserves, accessibility and haulage of considerable tonnages could present difficulties. The use of land vehicles for retrieval may be difficult or impossible. The clear cutting of forested areas in the immediate vicinity of a community is most unlikely to be acceptable for aesthetic reasons. For harvesting on the scale necessary to meet a community's total needs, it would be appropriate for the community to set up an operation responsible for the collection and sale of wood to residents. For many coastal Reserves, such an operation would almost certainly have to rely on water transport to haul timber to the community. The establishment of fixed facilities at the community for cutting logs to final size and storing would be advantageous. Chain saws for this purpose are a high maintenance item and not particularly appropriate for this scale of operation.

A definitive cost of supplying wood cannot be determined at this level of investigation and will be highly dependent on equipment cost factors and labour rates. For study purposes, a cost range of $20 to $30/m^3 is assumed, corresponding to $45 to $65/cord. This corresponds with a unit energy cost (before combustion) of $3.50 to $5.00/GJ, or allowing for combustion efficiency differences, about half that of heating with oil.

Wood Stove Operation

The retail cost of a durable free-standing, controlled-air wood stove is about $800; with the flue fittings and delivery included, an installed cost of $1,000 can be assumed. Short-life stoves are also available at much lower cost. Some problems have occurred with air tight stove operation, involving the build-up of tar residues in flue systems, creatng a potential fire hazard. Continuous operation under limited air ("cool" combustion) conditions cause tar products to condense. These products can be effectively purged by increasing the burn rate from time to time.

Wood immersed in sea water for any length of time absorbs salt. Subsequent combustion creates highly corrosive conditions with particularly aggressive effects on thin-wall flue fittings. (At Hartley Bay, where most of the wood used is salvaged from the sea, a few residents leave cut wood exposed to the elements for a number of months in order to leach out the salt. They report that after 4-5 years of operation, no replacement or repairs to stove equipment have been necessary.)

A1.5 GEOTHERMAL

This assessment of geothermal energy is restricted to hot water and/or steam available from below-ground sources. Hot springs are to be found at a number of sites in the province. These and other geothermal anomalies have been assessed in an unpublished study undertaken recently for the B.C. Ministry of Energy, Mines and Petroleum Resources. For the past number of years, B.C. Hydro has been exploring the Meager Mountain geothermal resource, located near Pemberton, as a potential source of steam for electrical power generation.

In the United States and elsewhere, geothermal steam is being used directly in major power installations, a process that dispenses with a conventional fossil fuel boiler. However, on a world scale, geothermal energy has been mainly harnessed for direct-use heating applications using hot water. Examples of these range from district heating systems for town needs (western U.S. and Iceland), central heating systems serving large residential apartment complexes (France), down to the individual heating of residences. In Oregon and Idaho, geothermal hot water sources have been used for building space heating for many decades.

In Canada in recent years, the federal Energy, Mines and Resources and other agencies have been researching the potential for direct-use applications. Particular attention has centred on the deep geothermal hot water resources (60°-100°C) of the Western Sedimentary Basin covering much of Saskatchewan and Alberta, and extending into northeastern British Columbia. Recent studies (Acres, March 1983; Sproule Associates, 1981) have shown that geothermal energy for direct use is capable of economically displacing oil and electrical heating.

A geothermal direct-use system typically comprises a pumped supply well located above the resource, a pipeline for conveying hot water to the point of use, heat exchanger(s), and a re-injection well for returning the cooled water back to the resource (re-charging). For deep resources (1000 - 3000 m) the principal cost is for exploration and well development. This cost can amount to 2-3 million dollars per well and can only be economically justified for large demands (15 - 20 GJ/h) using resource supply temperatures of around 60°C and higher, and a high annual utilization of the water sensible energy.

Provincial hot springs, on the other hand, offer a potential source of hot water, low development costs, and supply temperatures of up to 50°C and in some cases to 70°C. The economics of utilizing this surface-level resource hinge on the cost of piping hot water to the point of use. This is mainly a function of proximity to user points and the local terrain topography. Annual utilization can be enhanced by using the resource for year-round hot water heating in addition to water space heating.

A1.6 GASIFICATION

Gasification, a fuel conversion technology, involves the production of a gas with low to medium energy content obtained by the burning of such fuels as coal, wood or peat under oxygen-starved conditions. The product gas is a clean fuel suitable for firing in a conventional boiler or, potentially, in an internal combustion engine generator plant.

Gasification of coal and the associated power generation process is developmental and complex. The potential for this particular fuel conversion technology, with its reliance on coal supplies, is considered inappropriate for remote Reserves.

The following provides a brief review of wood gasification technology; the material is principally drawn from a study undertaken recently by Ontario Hydro (1982).

Gasification System

Wood gasification systems involve three elements: wood handling, the gasifier itself, and gas cleanup. The wood handling system can vary from an unsophisticated front-end loader approach to a sophisticated wood-unloading, sizing, transport, and storage system complete with automated controls. Non-uniformity of the wood fuel product with respect to size and moisture content, and such factors as freezing, storage bin bridging and control malfunctions contribute to bottle-necks in operation. Reduction of the raw wood to a wood chip feed product requires considerable power, and commercially available equipment is restricted to sizes more relevant to large forest industry wood chipping operations. Such wood preparation and handling facilities will require full time operator attendance and will likely be a source of high maintenance.

Wood gasifers fall into one of three types, classified as updraft, fluidized bed, and downdraft. Each operates on the principle of incomplete combustion of hydrocarbon material but produces different gas qualities having particular advantages and disadvantages depending on the application. The fluidized bed gasifer is the most complicated. The

updraft and downdraft designs are both fairly simple in concept. The downdraft type produces a product relatively low in tar and condensibles and is the principal contender for use with modified internal combustion engines. There are numerous downdraft gasifier designs on the market or being developed. Of these, the Duvant downdraft gasifer, a French design, appears to be in the forefront at the present time. In parallel with gasifier development, Duvant have developed a dual-fuel diesel engine for use with it, a combination giving a gas output of 12 GJ/h and engine output of either 460 kW or 720 kW. (Note: there are two engine sizes available but only one size of gasifier.)

The Imbert gasifier design (operating in conjunction with a modified Deutz diesel engine) is regarded to be the main competition to Duvant in the world market. Both of the companies are promoting their products mainly in Third World countries. Imbert have sold two units in Canada, of 60 kW and 120 kW outputs, the former to Saskatchewan Power Corporation for testing purposes. The Imbert gasifier is entirely manual: batch fuel feeding, light-up and control are all performed manually.

A gas cleanup system is required to remove particulates, tar and condensibles; particulates are removed by means of cyclone separators, while tar and condensibles are removed by washing with water, distillate oil or diesel fuel. The waste-water, contaminated by hydrocarbon compounds in the water washing process, requires treatment before disposal.

Internal Combustion Engines

Caterpillar and other North American engine manufacturers have yet to develop a diesel engine suitable for low to

medium energy gas. The Duvant diesel unit has a number of unique features including a proven dual-fuel capability on diesel and low energy gas, automatic diesel fuel control to suit gas quality and quantity conditions, and automatic control of engine and gasifier to handle rapid load changes and other fluctuating conditions that can be experienced during operation.

Hydro Quebec is actively considering the purchase of a Duvant gasifier-combustion engine system for further evaluation under operational conditions.

Spark-ignition engines can also be used. They require relatively few and simple modifications to convert to low-energy gas operation. For this reason most of the North American gasifier systems are being designed for use in conjunction with spark-ignition engines. Efficiencies are expected to be lower than those of the comparable compression ignition engine. Fluctuations in gas quality and quantity present serious engine performance problems and, so far, suitable control systems are not available. Propane is a possible support fuel option for remote installations. Further development and operating experience with spark-ignition engines is necessary before they can be considered acceptable for electrical generation.

Gasifier Wood Supplies at Remote Reserves

The Crippen study (1982) undertaken for DIAND examines the various aspects asssociated with securing an adequate wood supply, its collection, preparation and handling. The study dealt with Indian communities in a number of provinces (excluding British Columbia) and examined locations much more sparsely forested and with annual growths much more limited

than would be the case for remote Reserves in B.C. Terrain conditions were generally much more favourable for the harvesting and transport of wood to gasifier sites. For many of the B.C. Reserves, located in rugged terrain, suitable cost-effective methods for gathering wood supplies in quantities necessary to support a gasifier operation, need to be evaluated.

A1.7 COAL

The principal coal production centres lie in the southeastern and northeastern parts of the province. Metallurgical and thermal quality coal is currently being shipped by rail from a number of mine operations in the southeast to Vancouver for export to Japan. With the completion of the Northeast Coal Development in the near future, export coal will be sent by rail to loading facilities at Ridley Island near Prince Rupert. The present cost of clean thermal quality export coal (heating value, 27,000 kJ/kg) from the southeastern mine operations, F.O.B. Vancouver, ranges from $65 to $80/tonne, which includes a transport component of about $20/tonne.

The export-oriented operations are handling bulk quantities on a scale that does not readily lend itself to diverting small quantities to the domestic market. Additional handling and storage facilities would be necessary at the coastal bulk receiving terminals, a situation which would be received with considerable reluctance on the part of the coal operators.

At the present time no established wholesale distribution network is in place for the marketing of coal within the province. The few individual coal retail operations that exist rely on surface mine operations in Alberta for their supplies. Typically, these lower rank sub-bituminous Alberta

coals have heating values of around 17,000 kJ/kg (7,500 Btu/lb). The retailers' present cost, F.O.B. Vancouver area, is around $70/tonne which includes about $50/tonne for rail delivery. One retailer, serving residences in the Fraser Valley area, indicates annual sales of 1,000 to 1,500 tonnes in past years though this level of demand appears to be diminishing.

Review of Coal Applications

Compared to oil or natural gas, the industrial-scale use of coal, either to generate electricity or steam for heating, presents a number of special problems. Its bulk and irregular size, as-received, requires physically large and expensive facilities to crush, transport, store, reclaim and prepare for final firing. In addition, boiler volume requirements are significantly larger and the boiler design more expensive for a given heat release. Ash removal and its final disposal requires constant management of ash storage pile to avoid groundwater contamination from leachate action.

The control of boiler emissions, i.e. particulates, sulphur dioxide, and nitrogen oxides, also requires special attention and a significant cost is involved to meet environmental emission limits. For these and other reasons the use of coal for electrical generation is reserved for large scale plants of multi-hundred megawatt capacities in order to reduce the unit costs ($/kW of installed capacity) to economic levels.

Coal is technically more suitable for domestic space and hot water heating purposes, using stove type burners. Though not so convenient a fuel source as oil, this type of use is considered to be practical for heating small buildings. The

principal issue is its availability at an acceptable cost and, to a lesser extent, the acceptability of stack emissions. For space heating, coal could be used as a dual fuel in a conventional, controlled-air wood stove type of design.

Coal Deliveries to Remote Reserves

Assuming the use of Alberta sources of surface mined coal, with similar costs for delivery by rail to either Vancouver or Prince Rupert at $70/tonne, a means of final delivery to remote Reserves is required. A number of the interior remote Reserves appear to lie in fair proximity to the CN Rail route to Prince Rupert. A drop-off of cars at appropriate centres along the route could permit final road deliveries to these Reserves. Accessibility factors for these individual Reserves will need further examination in the detail. Other Reserves lie on tide water for which access by barge appears as a possibility.

For a coastal community of 250 people, similar to Hartley Bay, the present space heating demand would support an annual coal consumption of around 600 tonnes. Discussions with Rivtow Straits Ltd. indicate that this quality is small in relation to the carrying capacity of a medium size 2,000 tonne barge. For a single delivery within a 150 km radius of the port base (coal pick-up point) and assuming a 2 day round trip duration, the cost of barging would be of the order of $10,000. If a number of Reserves could be served in a similar round trip distance, overall savings in the delivered cost/tonne might be achieveable. The actual cost is affected by the duration of the round trip, a function of the number of off-loadings and access to docks under varying tidal conditions. For general evaluation purposes, an average

range for barge delivery of $15 to $20/tonne is assumed. Accordingly, the estimated delivered cost of coal, F.O.B. barges at the Reserves, ranges from $85 to $90/tonne. To this must be added a component to cover the cost of providing off-loading and central storage facilities at the Reserves.

The cost of off-loading and storage facilities is site dependent and affected by such factors as suitability of existing dock or float, methods employed for off-loading, methods of transporting, and access routes to a coal storage site. Barges can carry their own mechanical means for off-loading. Fixed equipment such as a simple conveyor system from the dock to the storage site would be grossly under-utilized for this occasional duty; some form of vehicle transport would be preferable.

The energy cost delivered to Reserves, but excluding a component for local handling facilities, could be in the region of $5.50/GJ. This compares with current heating oil costs of $9.00 to $10.00/GJ (or a marginal cost of about $12.00/GJ, based on imported oil prices). Coal prices are typically more stable than oil. Transportation represents the largest cost component so that the long term trend can be expected to generally follow domestic inflation patterns. The difference between present coal and oil costs and the potential for greater differences in the future provide a considerable margin, which could be potentially adequate to cover the provision of local off-loading/storage facilities, depending on site-specific conditions.

It is concluded that the logistics of delivery and resulting cost will inhibit the use of coal, particularly where wood is available as an alternative resource.

A1.8 SOLAR

The virtually limitless heat from the sun has long been viewed as the ideal source of energy. Solar energy has many important potential benefits to society, such as environmental cleanliness, renewability, free distribution and the possibility for reduced dependance on other non-renewable sources of energy. However, there are significant limitations to the availability of solar energy due to variation in solar radiation intensity resulting from daily, seasonal and annual weather cycles. As a result of these limitations it is usually necessary to provide costly energy storage facilities or, as is often the case, to provide an alternative energy supply for periods when solar energy is not available.

In British Columbia the available solar energy on an annual basis is relatively constant for most of the province. The daily average energy over the year for an optimum sloping surface varies fromm 12 MJ/M^2 to 15 MJ/m^2. Exceptions to this are the coastal areas including the Queen Charlottes and Prince Rupert which receive 15 to 20 percent less solar energy than do other areas.

An assessment of the practicability for utilizing solar energy requires a blend of ideological concepts and hard economic facts. Many experimental and related economic studies have been made to determine the feasibility of various applications of solar energy. The results of these appear to indicate that solar energy as a viable energy source may have limited application in the case of remote communities.

The most common solar energy systems are those used for space heating of buildings and for hot water heating. Solar energy can also be converted directly to electrical energy by photovoltaic cells; however this application has not found wide-spread usage for most practical purposes.

Solar energy for heating is utilized in two basic systems: the active system and the passive system.

- In the active system the energy is usually collected in solar cells or panels exposed to the sun. The panels are made from special heat absorbing materials and are well insulated and constructed to prevent the escape of the captured energy. This energy is then delivered to the building by pumps or fans using a transfer medium such as water or air.

- In the passive system the solar energy is captured directly within the building through windows or on panels which transfer the heat by direct contact with the building air. No mechanical means are used for this transfer.

For most remote communities the most practicable applications of solar energy systems would be for the passive system of space heating. Active systems may have an application for hot water heating. In the passive space heating system, building modifications are made and insulation levels increased in order to capture as much solar energy as possible while at the same time minimizing heat losses. Building modifications would consist of increasing window areas on southern exposures and reducing the areas on northern exposures. Windows would require double glazing to reduce losses, although single glazing in combination with

night insulation is slightly superior. Also, double glazing in combination with night insulation will net more heat gain than will triple glazing. Night insulation consists simply of insulated shutters or sliding doors which can be closed over the windows at night.

The cost of building modifications and installations may be substantial in order to take best advantage of the potential energy savings. These costs will always be in additionn to the existing fuel heating system, since the back-up system is required to be installed in any case for periods when solar energy is not available. All systems require high levels of insulation to minimize heat losses. A degree of energy awareness is also required to ensure that night insulation, if used, is installed and removed each day as required.

A1.9 BIOGAS GENERATION

Biogas, comprising two-thirds methane, can be produced from organic waste with a heating value of 21-25 MJ/m^3. The process involves the anaerobic fermentation of organic products resulting in methane, carbon dioxide, hydrogen, traces of other gases and the production of some heat. The residue is hygienic, rich in nutrients, and high in nitrogen. Potentially harmful organisms are killed by the absence of oxygen during the fermentation process. In rural India there are more than 50,000 small scale biogas producers, and over half a million reported in Mainland China (Acres, 1982). A demonstration biogas unit in Alaska uses crab processing wastes. The technology is well established, and unit outputs range from "one cow" size (20-30 MJ/day) to over 3,000 GJ/day.

The process involves mixing organic waste with water to produce a slurry which is introduced into an air-tight containment vessel, the digester. Heat is added to the digester to accelerate the process, while a paddle wheel or other agitation device is used to stir the slurry in the digester. The gas forms above the surface of the slurry while the residue is drawn off for use as a fertilizer.

Biogas production is optimal in two temperature ranges, 30°-40°C, and 50°-60°C, although the digestion process occurs from freezing to about 70°C. Fermentation, however, is less stable in the higher range so that units are usually designed to operate at the lower range. Typically, from one-third to one-half of the produced gas energy content is required to heat the process.

The heating value of the gas product is approximately two-thirds that of natural gas, which makes it technically suitable for a number of direct heating applications. Its use will depend on availability of abundant supplies of organic waste materials and preferably a single point of consumption to minimze cost of local distribution.

A1.10 NATURAL GAS AND PROPANE

The availability of natural gas from the provincial system could potentially provide a community with most or all of its energy needs including compressed gas for transportation. However, for this study, a community connected to the gas grid is no longer classified as remote.

An established network exists in the province for the distribution and marketing of liquid propane. Propane is barged or trucked to major centres from which it is distributed to

smaller outlets for sale to users in containers of, typically, 9 kg and 45 kg capacity; 180 kg capacity containers are less commonly used. Skid mounted propane tanks of 1550 kg (3,400 lb.) capacity are also available to larger users, while road tanker/semi-trailer combinations can provide bulk deliveries of up to 11,000 kg and barge deliveries of up to 40,000 kg (three 13,500 kg tanks).

From discussions with ICG Canadian Propane Ltd., a major distributor in the province, bulk barge deliveries to remote coastal communities are hampered by agreements relating to the barging and unloading of materials; barging tariffs are based on the cost of delivery from the Port of Vancouver, while unloading periods in excess of 2 hours require that longshoremen perform the work of pumping propane to shore based storage tanks. Barge access under varying tidal conditions can also be a problem. The alternative of using a number of 3200 kg containers (1550 kg propane capacity) also requires that appropriate lifting facilities be provided at the dock along with means of moving them to a central propane storage location.

Propane is variously used as an alternative energy source to electricity in such applications as cooking, hot water and clothes dryer heating, and refrigeration. Propane is also used for space heating in some communities (Sigma, 1983), although generally only where prices are particularly low and propane supplies are readily accessible.

The Sigma (1983) survey of remote communities shows propane prices ranging from $20 to $60 with a high of $67 per 45 kg container; the median price level appears to be around $35 to $40 per container. The extremes correspond with a fuel energy cost before combustion of $9 to $29/GJ. By comparison

the survey shows heating oil prices ranging from 27¢ to 60¢/L, or about $7 to $16/GJ. Generally, prices of the two fuels at any community follow each other with the cost of propane energy ($/GJ) appearing to remain at some level above that of oil. The higher cost of both fuels being experienced by some communities presumably reflect remoteness from fuel supply centres with perhaps some opportunity pricing component included.

For communities relying on diesel power for electrical generation, propane energy costs for cooking and hot water heating applications are significantly less than of marginally priced electricity at 15¢ to 20¢/kWh ($44 to $59/GJ). (Where the user pays only a fixed monthly rate for electricity and experiences no other restraints on electrical consumption, the marginal cost of electricity is zero and propane becomes decidedly less attractive.) The economics of propane use for refrigerators and freezers appears to be marginal. Such appliances typically consume 20 kg/month of propane as against 120-150 kWh/month of electricity. Relative to the marginal or incremental price of electricity, the monthly propane energy cost saving amounts to only a few dollars while the initial outlay is from $600 to $1000 greater for propane appliances. Some improvement in favour of propane can be expected if a world oil pricing scenario is assumed or if the full cost of diesel generation (perhaps 30¢/kWh) is borne by the user.

For space heating applications the economics of propane versus oil is affected by the type of propane heating device used. Propane can be burned directly in living spaces; a flue is not essential for venting the combustion products, carbon dioxide and water vapour. The heating efficiency is then almost 100 percent, as compared to oil at 50 to 65

percent, depending on equipment. This situation favours propane use. However, water vapour condensation on cold surfaces and its tendency to saturate insulation in ceilings and walls, particularly in the absence of proper vapour barrier protection, is a detrimental feature of direct space heating with propane.

For significant space heating loads, exhaust venting becomes necessary, in which case the economics of propane heat are less favourable. A practical factor restraining greater use of propane is the difficulty that some remote communities face in the transport of containers to external supply sources. The alternative of installing bulk storage facilities at remote communities, and the consequent propane costs, would require e amination of specific circumstances.

APPENDIX A2
AVERAGE APPLIANCE ENERGY REQUIREMENTS

Based on survey of appliances at 15 Hartley Bay residences including the health clinic.

(Sample calculation:

$$\frac{9 \text{ Coffee Percolators}}{15 \text{ houses}} \times 6 \text{ kWh/mon.} \times 12 \text{ mon.} \times 3.6 \text{ MJ/kWh}$$

= 155 MJ/House, per year)

Appliance	Number	Average Annual MJ/House
Fans	6	138
Coffee Percolators	9	155
Dishwashers	1	-
Kettles	4	253
Toasters	10	576
Dryers	4 Propane, 7 Electric	2,376
Irons	13	150
Washers	15	216
Refrigerators	15	6,480
Freezers	18	6,221
Stereos	11	348
Radios	17	196
Televisions	17	1,469
Lights	15	3,024
Vacuums	10	86
Heaters (fans)	4 Furnaces	576
Total Avg. Demand		22,264
Cooking		
Ranges	14 Propane, 1 Electric	4,320
TOTAL APPLIANCES & COOKING		26,584 MJ
DIAND Average @ 721 kWh/mo		31,147 MJ
Difference		4,563

Note: Much of the difference between the DIAND averages and Hartley Bay are explained by the fact that most houses do not have dishwashers, forced air heating fans and some of the smaller appliances.

APPENDIX A3
ENERGY AUDIT SURVEY FORM

Date: _____

Building No. _____ Location _____
Occupancy: Type _____ No. Adults _____ No. Children _____
Dimensions - LxW _____ = _____ sq. ft.
Enclosed Volume _____ cu. ft.
Ext. Height above Ground _____
Basement _____ Basement Depth Below Ground _____ ft.
Crawl Space _____ Ht. _____ ft Skirt _____

CONSTRUCTION: Year _____ Foundation Type _____
Walls Ext. _____ Walls Int. _____
Ceiling _____ Roof _____
Windows: Type _____ No. _____ Total Area _____
Doors: Type _____ No. _____ Total Area _____
Insulation: Walls _____ Ceiling _____
Floors _____ Other _____
Air Leakage: Windows _____ Doors _____
Vents _____ Chimneys _____
Siting: _____
Windbreak: _____
Passive Solar: _____

APPLIANCES:

Kitchen:	Range	_____	Dishwasher	_____	Kettle _____
	Fan	_____	Coffee Perc.	_____	Toaster Oven _____
Laundry:	Dryer	_____	Iron	_____	Washer _____
Entertainment:	HI FI	_____	Radio	_____	TV _____
Water Heater:	_____				
Food:	Refrigerator	_____	Freezer	_____	
Lighting:	Fluorescent	_____	Incandescent	_____	
Other:	Vacuum Cleaner	_____	Misc.	_____	

HEATING: Mode _____ Controls _____
Furnace: Type _____ Size _____
Heater: Type _____ Size _____
Baseboard: _____ Total Installed kW _____

ENERGY CONSUMPTION: Electricity (kWh) _____
Oil (Gals or Litres) _____
Propane (lbs) _____
Gasoline (Gals or Litres) _____
Wood (Cords) _____

COMMENTS: _____

APPENDIX B1
DEMOGRAPHIC PROJECTIONS

ASSUMPTIONS:
Population Growth: 1.5% per annum to 1993
1.0% per annum to 2003
Type X houses demolished at rate of 5 units per year until depleted.
Type A houses demolished at a rate of 5 units per year for 1986-1987 and at a rate of 2 per year thereafter.
Type B houses unchanged.
Type C houses replace demolished houses and increase by one unit for each increase of 4 in population.

YEAR	1983	1984	1985	1986	1987	1988
Population	234	236	241	245	248	252
Housing Stock:						
Type X	10	5	0	0	0	0
Type A	30	30	30	25	20	18
Type B	20	20	20	20	20	20
Type C	0	6	12	18	24	27
Total Houses	60	61	62	63	64	65

1989	1990	1991	1992	1993	1994	1995	1996
256	260	264	268	272	274	277	280
0	0	0	0	0	0	0	0
16	14	12	10	8	6	4	2
20	20	20	20	20	20	20	20
29	32	35	38	41	44	47	49
65	66	67	68	69	70	71	71

1997	1998	1999	2000	2001	2002	2003
283	285	288	291	294	297	300
0	0	0	0	0	0	0
0	0	0	0	0	0	0
20	20	20	20	20	20	20
52	53	54	54	55	56	56
72	73	74	74	75	76	76

APPENDIX B2
HARTLEY BAY ENERGY REQUIREMENTS - BASE CASE

VARIABLES:

Population:		234	
Housing Stock:		Number	Avg. sq.m.
All types: one floor, no bsmt., 15% windows:			
Type X: no insulation		11	71
Type A: R7-ceiling, R7-walls, single glazed		31	93
Type B: R20-ceiling, R12 walls, R12 floors,dbl glaze		17	98
Type C: R28-ceiling, R20-walls, R20 floors,dbl glaze		1	112
Climate: degree days		4000	

	$ per Unit	$ per GJ	Efficiency	$ per net GJ
Current Fuel Prices:				
Diesel Fuel: per liter	$0.46	$11.79	32.3	$36.52
Heating Oil: per liter	$0.38	$9.74	50	$19.49
Propane: per liter	$0.38	$15.83	65	$24.36
Wood: per cord	$55.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	26.748	294.1	50	588.3	9.74	5731.92
	Windows/Doors	12.531	137.8	50	275.7	9.74	2686.13
	Ceiling Losses	26.479	291.3	50	582.5	9.74	5676.00
	Floor Losses	26.839	295.2	50	590.5	9.74	5753.18
	Wall Losses	18.997	209.0	50	417.9	9.74	4072.18
		111.586	1227.4		2454.9		23919.41
Type A	Infiltration	32.956	1021.6	50	2043.3	9.74	19908.77
	Windows/Doors	10.552	327.1	50	654.2	9.74	6374.49
	Ceiling Losses	11.969	371.0	50	742.1	9.74	7230.51
	Floor Losses	34.485	1069.0	50	2138.1	9.74	20832.65
	Wall Losses	13.686	424.3	50	848.5	9.74	8267.73
		103.648	3213.1		6426.2		62613.95
Type B	Infiltration	27.101	460.7	50	921.4	9.74	8978.05
	Windows/Doors	11.291	191.9	50	383.9	9.74	3740.50
	Ceiling Losses	6.968	118.5	50	236.9	9.74	2308.37
	Floor Losses	8.068	137.5	50	275.0	9.74	2679.42
	Wall Losses	12.476	212.1	50	424.2	9.74	4133.09
		65.924	1120.7		2241.4		21839.43
Type C	Infiltration	20.989	21.0	50	42.0	9.74	409.02
	Windows/Doors	11.043	11.0	50	22.1	9.74	215.20
	Ceiling Losses	5.973	6.0	50	11.9	9.74	116.40
	Floor Losses	6.826	6.8	50	13.7	9.74	133.02
	Wall Losses	12.515	12.5	50	25.0	9.74	243.88
		57.346	57.3		114.7		1117.51
Hot Water	Households	24.624	1477.4	50	2954.9	9.74	28791.14
Cooking	Households	4.320	259.2	65	398.8	15.83	6313.85
Lights/Appliances	Households	22.264	1335.8	32.3	4135.7	11.79	48780.38
TOTALS			9691.1		18726.5		193375.66
PER CAPITA ENERGY USE			37.1				826.39
PER HOUSEHOLD ENERGY USE			144.9				3222.93
SCHOOL: Type B constr.	Area: (sq.m.)	753.000					
Space Heating	Infiltration		208.2	55	378.6	9.74	3689.00
	Windows/Doors		31.3	55	56.9	9.74	554.46
	Ceiling Losses		53.5	55	97.3	9.74	948.49
	Floor Losses		62.1	55	113.0	9.74	1100.95
	Wall Losses		34.6	55	62.9	9.74	612.66
Hot Water	H'hold Equiv.	2.000	49.2	55	89.5	9.74	872.46
Lights/Appliances	Specified	1.000	230.4	32.3	713.3	11.79	8413.43
COMMERCIAL: Type A	Area: (sq.m.)	174.000					
Space Heating	Infiltration		61.7	50	123.3	9.74	1201.57
	Windows/Doors		14.4	50	28.9	9.74	281.27
	Ceiling Losses		22.4	50	44.8	9.74	436.39
	Floor Losses		64.5	50	129.0	9.74	1257.32
	Wall Losses		18.7	50	37.4	9.74	364.80
Hot Water	H'hold Equiv.	0.000	0.0	50	0.0	9.74	0.00
Lights/Appliances	Specified	1.000	54.0	32.3	167.2	11.79	1971.90
COMMUNITY BLDGS.							
Type A constr.	Area: (sq.m.)	808.000					
Space Heating	Infiltration		286.3	50	572.7	9.74	5579.70
	Windows/Doors		31.1	50	62.2	9.74	606.11
	Ceiling Losses		104.0	50	208.0	9.74	2026.45
	Floor Losses		299.6	50	599.2	9.74	5838.58
	Wall Losses		40.3	50	80.7	9.74	786.12
Hot Water	H'hold Equiv.	2.000	49.2	50	98.5	9.74	959.70
Lights/Appliances	Specified	1.000	44.8	32.3	144.9	11.79	1708.98
Type B constr.	Area: (sq.m.)	589.000					
Space Heating	Infiltration		162.9	50	325.8	9.74	3174.11
	Windows/Doors		27.7	50	55.4	9.74	539.42
	Ceiling Losses		41.9	50	83.8	9.74	816.11
	Floor Losses		48.6	50	97.2	9.74	947.29
	Wall Losses		30.6	50	61.2	9.74	596.03
Hot Water	H'hold Equiv.	3.000	73.9	50	147.7	9.74	1439.56
Lights/Appliances	Specified	1.000	68.4	32.3	211.8	11.79	2497.74
Street Lighting	Specified	1.000	164.4	32.3	323.2	11.79	3812.34
TOTAL DEMAND			11012.0		23840.9		246408.59
TOTAL PER CAPITA			47.06		101.88		1053.03
TOTAL PER HOUSEHOLD			183.53		397.35		4106.81

APPENDIX B3
HARTLEY BAY ENERGY REQUIREMENTS - ALTERNATIVE 2

VARIABLES:

Population: 224

Housing Stock	Number	Avg. sq.m.
All types: one floor, no bsmt., 15% windows:		
Type X: noninsulation	11	71
Type A: R7-ceiling, R7-walls, single glazed	31	93
Type B: R20-ceiling, R12-walls, R12 floor/slab, glaze	17	98
Type C: R28-ceiling, R20-walls, R20 floor/slab, glaze	1	112

Climate: degree days

Current Fuel Prices:	$ per Unit	$ per GJ	Efficiency	$ per Net GJ
Diesel Fuel: per liter	80.45	$11.79	32.3	$36.52
Heating Oil: per liter	80.38	$9.74	50	$19.49
Propane: per liter	80.38	$15.42	65	$24.26
Wood: per cord	$55.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	26.740	294.1	50	588.3	9.74	5731.92
	Windows/Doors	12.531	137.8	50	275.7	9.74	2686.13
	Ceiling Losses	26.479	291.3	50	582.5	9.74	5676.00
	Floor Losses	26.829	295.2	50	590.5	9.74	5753.18
	Wall Losses	18.997	209.0	50	417.9	9.74	4072.18
		111.586	1227.4		2454.9		23919.41
Type A	Infiltration	32.956	1021.6	50	2043.3	9.74	19908.77
	Windows/Doors	10.552	327.1	50	654.2	9.74	6374.49
	Ceiling Losses	11.969	371.0	50	742.1	9.74	7230.51
	Floor Losses	11.513	356.9	50	713.8	9.74	6955.05
	Wall Losses	13.535	424.3	50	845.5	9.74	8237.73
		80.575	2571.0		5001.9		48706.55
Type B	Infiltration	27.101	460.7	50	921.4	9.74	8976.35
	Windows/Doors	11.001	191.5	50	383.9	9.74	3741.50
	Ceiling Losses	9.349	159.5	50	318.9	9.74	3108.37
	Floor Losses	9.166	157.5	50	275.0	9.74	3679.42
	Wall Losses	12.475	212.1	50	424.2	9.74	4133.09
		65.324	1221.7		2241.4		21835.43
Type C	Infiltration	20.869	21.0	50	42.0	9.74	409.22
	Windows/Doors	11.043	11.0	50	22.1	9.74	215.20
	Ceiling Losses	5.971	6.0	50	11.9	9.74	115.43
	Floor Losses	5.826	5.8	50	11.7	9.74	113.32
	Wall Losses	12.815	12.8	50	25.6	9.74	243.66
		57.347	57.3		114.7		1117.31
Hot Water	Households	24.324	1477.4	50	2954.9	9.74	28791.14
Cooking	Households	4.320	259.2	65	398.6	15.43	6313.05
Lights/Appliances	Households	72.264	1035.1	32.3	4135.7	11.79	48750.23
			737.1		17300.1		17940.16
SUB TOTAL RESID. USE			7471.1				277.9
SUB TOTAL HOUSEHOLD ENERGY USE			1221.1				2991.74
RESID: Type B constr.	Area: (sq.m.)	782.117					
Space Heating	Infiltration		226.0	55	372.6	9.74	3629.10
	Windows/Doors		31.3	55	56.9	9.74	554.46
	Ceiling Losses		53.5	55	97.3	9.74	948.49
	Floor Losses		52.1	55	119.0	9.74	1160.55
	Wall Losses		34.5	55	62.9	9.74	612.55
Hot Water	H'hold Equiv.	1.000	49.2	55	89.5	9.74	871.46
Lights/Appliances	Specified	1.000	230.4	32.3	713.3	11.79	8411.43
COMMERCIAL: Type A	Area: (sq.m.)	174.000					
Space Heating	Infiltration		61.7	50	123.3	9.74	1201.27
	Windows/Doors		14.4	50	28.9	9.74	281.27
	Ceiling Losses		22.4	50	44.8	9.74	435.29
	Floor Losses		64.5	50	129.0	9.74	1257.32
	Wall Losses		18.7	50	37.4	9.74	364.40
Hot Water	H'hold Equiv.	0.000	0.0	50	0.0	9.74	0.00
Lights/Appliances	Specified	1.000	34.0	32.3	167.0	11.79	1971.30
COMMUNITY BLDGS.							
Type A constr.	Area: (sq.m.)	806.000					
Space Heating	Infiltration		286.3	50	572.7	9.74	5577.70
	Windows/Doors		31.1	50	62.2	9.74	606.11
	Ceiling Losses		104.0	50	208.0	9.74	2025.45
	Floor Losses		299.2	50	598.3	9.74	5827.68
	Wall Losses		40.3	50	80.7	9.74	785.82
Hot Water	H'hold Equiv.	1.000	49.2	50	98.5	9.74	959.37
Lights/Appliances	Specified	1.000	40.8	32.3	144.9	11.79	1708.9
Type B constr.	Area: (sq.m.)	849.000					
Space Heating	Infiltration		1.1.1	50	325..	9.74	3170.11
	Windows/Doo..		34..	50	68..	9.74	664.42
	Ceiling Losses		41.9	50	83.8	9.74	816.11
	Floor Losses		49.6	50	97.2	9.74	947.01
	Wall Losses		30.5	50	61.2	9.74	596.03
Hot Water	H'hold Equiv.	3.027	73.5	50	147.7	9.74	1439.58
Lights/Appliances	Specified	1.000	68.4	32.3	211.3	11.79	2487.74
Street Lighting	Specified	1.000	104.4	32.3	323.8	11.79	3818.34
TOTAL DEMAND			19259.8				232531.18
TOTAL PER CAPITA			**44.02**				**993.72**
TOTAL PER HOUSEHOLD			**171.66**				**3875.52**

APPENDIX B4
HARTLEY BAY ENERGY REQUIREMENTS - PROJECTIONS

Year: 1885

VARIABLES: 1985

Population: 241

Housing Stock:

	Number	Avg. sq.m.
All types: one floor, no bsmt., 15% windows;	1	71
Type X: no insulation	31	93
Type A: R7-ceiling, R7-walls, single glazed	17	98
Type B: R20-ceiling, R12 walls, R12 floors,dbl glaze	13	112
Type C: R28-ceiling, R20-walls, R20 floors,dbl glaze		

Climate: degree days

Current Fuel Prices:

	$ per Unit	$ per GJ	Efficiency	$ per net GJ
Diesel Fuel: per liter	$0.45	$11.79	32.3	$36.52
Heating Oil: per liter	$0.38	$9.74	50	$19.49
Propane: per liter	$0.38	$15.83	65	$24.36
Wood: per cord	$55.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	26.740	26.7	50	53.5	9.74	521.08
	Windows/Doors	12.531	12.5	50	25.1	9.74	244.19
	Ceiling Losses	26.479	26.5	50	53.0	9.74	516.00
	Floor Losses	26.830	26.8	50	53.7	9.74	523.02
	Wall Losses	18.997	19.0	50	38.0	9.74	370.20
		111.586	111.5		223.2		2174.49
Type A	Infiltration	32.956	1021.5	50	2043.0	9.74	[illegible]
	Windows/Doors	10.552	327.1	50	654.2	9.74	6371.48
	Ceiling Losses	11.969	371.0	50	742.1	9.74	7228.82
	Floor Losses	[illegible]	[illegible]	50	[illegible]	9.74	20632.45
	Wall Losses	13.683	424.3	50	848.5	9.74	8267.73
		103.948	3223.1		6429.2		62623.75
Type B	Infiltration	27.101	[illegible]	50	321.4	9.74	3076.05
	Windows/Doors	[illegible]	192.9	50	385.7	9.74	3760.30
	Ceiling Losses	5.953	119.5	50	238.9	9.74	2302.27
	Floor Losses	6.360	[illegible]	50	272.1	9.74	2649.42
	Wall Losses	12.476	212.1	50	424.2	9.74	4133.09
		55.924	1120.7		2241.4		21839.42
Type C	Infiltration	20.369	272.9	50	545.7	9.74	5317.02
	Windows/Doors	11.043	143.5	50	287.1	9.74	2797.56
	Ceiling Losses	5.973	77.5	50	155.0	9.74	1511.15
	Floor Losses	6.823	88.7	50	177.5	9.74	1729.24
	Wall Losses	12.559	162.7	50	325.4	9.74	3170.46
		57.245	745.5		1491.0		14527.65
Hot Water	Households	24.304	1826.7	60	3053.4	9.74	29750.84
Cooking	Households	[illegible]	387.2	35	1107.0	15.83	6824.32
Lights/Appliances	Households	21.304	1600.4	35.3	4533.1	11.79	53406.30
			8358.5		18120.6		187837.06
TOTALS							779.41
PER CAPITA ENERGY USE			34.7				
PER HOUSEHOLD ENERGY USE			134.9				1029.63

APPENDIX B4 - Cont'd.

Year: 1990

VARIABLES:

1990

Population: 260

Housing Stock:

	Number	Avg. sq.m.
All types: one floor, no bsmt., 15% windows;		
Type X: no insulation	0	71
Type A: R7-ceiling, R7-walls, single glazed	15	93
Type B: R20-ceiling, R12 walls, R12 floors,dbl glaze	17	98
Type C: R28-ceiling, R20-walls, R20 floors,dbl glaze	34	112

Climate: degree days

Current Fuel Prices:

	$ per Unit	$ per GJ	Efficiency	$ per net GJ
Diesel Fuel: per liter	$0.46	$11.79	32.3	$36.52
Heating Oil: per liter	$0.38	$9.74	50	$19.49
Propane: per liter	$0.38	$15.83	65	$24.36
Wood: per cord	$55.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	26.740	0.0	50	0.0	9.74	0.00
	Windows/Doors	12.531	0.0	50	0.0	9.74	0.00
	Ceiling Losses	26.479	0.0	50	0.0	9.74	0.00
	Floor Losses	26.839	0.0	50	0.0	9.74	0.00
	Wall Losses	18.997	0.0	50	0.0	9.74	0.00
		111.586	0.0		0.0		0.00
Type A	Infiltration	32.956	494.3	50	988.7	9.74	9633.28
	Windows/Doors	10.552	158.3	50	316.5	9.74	3084.43
	Ceiling Losses	11.969	179.5	50	359.1	9.74	3498.63
	Floor Losses	34.485	517.3	50	1034.5	9.74	10080.22
	Wall Losses	13.685	205.3	50	410.6	9.74	4000.51
		103.648	1554.7		3109.4		30297.07
Type B	Infiltration	27.101	460.7	50	921.4	9.74	8978.35
	Windows/Doors	11.291	191.9	50	383.9	9.74	3740.50
	Ceiling Losses	6.956	118.3	50	236.6	9.74	2306.37
	Floor Losses	8.088	137.5	50	275.0	9.74	2679.42
	Wall Losses	12.475	212.1	50	424.2	9.74	4133.09
		65.924	1120.7		2241.4		21837.43
Type C	Infiltration	20.989	713.6	50	1427.3	9.74	13906.81
	Windows/Doors	11.043	375.5	50	751.0	9.74	7315.70
	Ceiling Losses	5.973	203.1	50	406.2	9.74	3957.47
	Floor Losses	6.826	232.1	50	464.2	9.74	4522.63
	Wall Losses	12.515	425.5	50	851.0	9.74	8291.97
		57.346	1949.8		3899.5		37995.36
Hot Water	Households	24.524	1625.2	50	3250.4	9.74	31670.25
Cooking	Households	4.120	285.1	65	438.5	15.83	6945.23
Lights/Appliances	Households	22.264	1469.4	32.3	4549.3	11.79	53658.41
TOTALS			8004.9		17488.7		182405.78
PER CAPITA ENERGY USE			30.8				701.56
PER HOUSEHOLD ENERGY USE			121.3				2763.72

APPENDIX B4 - Cont'd.

Year: 1995

VARIABLES:

			1995
Population:	277		
Housing Stock:	Number	Avg. sq.m.	
All types: one floor, no bsmt., 15% windows:			
Type X: no insulation	0	71	
Type A: R7-ceiling, R7-walls, single glazed	5	93	
Type B: R20-ceiling, R12 walls, R12 floors,dbl glaze	17	98	
Type C: R28-ceiling, R20-walls, R20 floors,dbl glaze	49	112	

Climate: degree days

Current Fuel Prices:	$ per Unit	$ per GJ	Efficiency	$ per net GJ
Diesel Fuel: per liter	$0.46	$11.79	32.3	$36.52
Heating Oil: per liter	$0.36	$9.74	80	$12.49
Propane: per liter	$0.38	$15.83	65	$24.36
Wood: per cord	$55.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	26.740	0.0	50	0.0	9.74	0.00
	Windows/Doors	12.531	0.0	50	0.0	9.74	0.00
	Ceiling Losses	26.479	0.0	50	0.0	9.74	0.00
	Floor Losses	26.839	0.0	50	0.0	9.74	0.00
	Wall Losses	18.997	0.0	50	0.0	9.74	0.00
		111.586	0.0		0.0		0.00
Type A	Infiltration	32.956	164.8	50	329.6	9.74	3211.09
	Windows/Doors	10.552	52.8	50	105.5	9.74	1028.14
	Ceiling Losses	11.965	59.8	50	119.7	9.74	1166.21
	Floor Losses	34.485	172.4	50	344.8	9.74	3360.07
	Wall Losses	13.586	67.9	50	136.9	9.74	1333.50
		103.648	518.2		1036.5		10099.02
Type B	Infiltration	27.102	450.7	50	901.4	9.74	8778.05
	Windows/Doors	11.291	187.8	50	383.6	9.74	3740.50
	Ceiling Losses	6.958	115.8	50	235.9	9.74	2308.37
	Floor Losses	8.068	137.8	50	275.6	9.74	2679.42
	Wall Losses	12.476	211.1	50	424.2	9.74	4133.09
		65.924	1120.7		2241.4		21639.43
Type C	Infiltration	20.989	1028.5	50	2056.9	9.74	20041.88
	Windows/Doors	11.043	541.1	50	1082.2	9.74	10544.56
	Ceiling Losses	5.973	292.7	50	585.4	9.74	5703.41
	Floor Losses	6.825	334.5	50	669.0	9.74	6517.91
	Wall Losses	12.515	613.2	50	1226.5	9.74	11950.20
		57.345	2810.0		5619.9		54758.05
Hot Water	Households	24.524	1746.3	50	3496.6	9.74	34069.51
Cooking	Households	4.320	305.7	65	471.3	15.83	7471.36
Lights/Appliances	Households	22.264	1580.7	32.3	4893.9	11.79	57723.45
			8024.7		17760.2		185960.85
TOTALS							
PER CAPITA ENERGY USE			29.2				671.34
PER HOUSEHOLD ENERGY USE			113.9				2619.17

APPENDIX B4 - Cont'd.

Year: 2000

VARIABLES:

			2000
Population:	291		
Housing Stock:	Number	Avg. sq.m.	
All types: one floor, no bsmt., 15% windows;			
Type X: no insulation	0	71	
Type A: R7-ceiling, R7-walls, single glazed	0	93	
Type B: R20-ceiling, R12 walls, R12 floors,dbl glaze	17	98	
Type C: R28-ceiling, R20-walls, R20 floors,dbl glaze	57	112	
Climate: degree days			

Current Fuel Prices:	$ per Unit	$ per GJ	Efficiency	$ per net GJ
Diesel Fuel: per liter	$0.46	$11.79	32.3	$36.82
Heating Oil: per liter	$0.38	$9.74	50	$19.49
Propane: per liter	$0.36	$15.83	65	$24.36
Wood: per cord	$55.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	26.740	0.0	50	0.0	9.74	0.00
	Windows/Doors	12.531	0.0	50	0.0	9.74	0.00
	Ceiling Losses	26.479	0.0	50	0.0	9.74	0.00
	Floor Losses	26.839	0.0	50	0.0	9.74	0.00
	Wall Losses	18.997	0.0	50	0.0	9.74	0.00
		111.586	0.0		0.0		0.00
Type A	Infiltration	32.956	0.0	50	0.0	9.74	0.00
	Windows/Doors	10.552	0.0	50	0.0	9.74	0.00
	Ceiling Losses	11.969	0.0	50	0.0	9.74	0.00
	Floor Losses	34.485	0.0	50	0.0	9.74	0.00
	Wall Losses	13.686	0.0	50	0.0	9.74	0.00
		103.648	0.0		0.0		0.00
Type B	Infiltration	27.101	460.7	50	921.4	9.74	8978.05
	Windows/Doors	11.291	191.9	50	383.9	9.74	3740.50
	Ceiling Losses	6.963	118.3	50	236.9	9.74	2308.37
	Floor Losses	8.088	137.5	50	275.0	9.74	2679.42
	Wall Losses	12.476	212.1	50	424.2	9.74	4133.09
		65.924	1120.7		2241.4		21839.43
Type C	Infiltration	20.989	1196.4	50	2392.8	9.74	23314.02
	Windows/Doors	11.043	629.5	50	1258.9	9.74	12266.23
	Ceiling Losses	5.973	340.5	50	680.9	9.74	6634.58
	Floor Losses	6.826	389.1	50	778.2	9.74	7582.06
	Wall Losses	12.515	713.4	50	1426.7	9.74	13901.25
		57.346	3268.7		6537.4		63698.14
Hot Water	Households	24.624	1822.2	50	3644.4	9.74	35509.07
Cooking	Households	4.320	319.7	65	491.8	15.83	7787.08
Lights/Appliances	Households	22.264	1647.5	32.3	5100.7	11.79	60162.46
TOTALS			8178.3		18015.8		188996.19
PER CAPITA ENERGY USE			28.1				649.47
PER HOUSEHOLD ENERGY USE			110.5				2554.60

APPENDIX B4 - Cont'd.

Year: 2003

VARIABLES:

		2003	
Population:			
Housing Stock:	300 Number	Avg. sq.m.	
All types: one floor, no bsmt., 15% windows:			
Type X: no insulation	0	71	
Type A: R7-ceiling, R7-walls, single glazed	0	93	
Type B: R20-ceiling, R12 walls, R12 floors,dbl glaze	17	98	
Type C: R28-ceiling, R20-walls, R20 floors,dbl glaze	39	112	
Climate: degree days			

Current Fuel Prices:	$ per Unit	$ per GJ	Efficiency	$ per net GJ
Diesel Fuel: per liter	$0.46	$11.79	32.3	$36.52
Heating Oil: per liter	$0.38	$9.74	50	$19.49
Propane: per liter	$0.38	$15.83	65	$24.36
Wood: per cord	$35.00	$4.23	38	$11.13

END USE	Demand Class	Demand per House (GJ)	Total Net Energy Demand (GJ)	Conversion Efficiency Factor (%)	Gross Energy Demand (GJ)	Energy Unit Price ($)	Total Energy Costs ($)
RESIDENTIAL:							
Space Heating							
Type X	Infiltration	25.740	0.0	50	0.0	9.74	0.00
	Windows/Doors	12.531	0.0	50	0.0	9.74	0.00
	Ceiling Losses	26.479	0.0	50	0.0	9.74	0.00
	Floor Losses	26.639	0.0	50	0.0	9.74	0.00
	Wall Losses	18.997	0.0	50	0.0	9.74	0.00
		111.586	0.0		0.0		0.00
Type A	Infiltration	32.956	0.0	50	0.0	9.74	0.00
	Windows/Doors	10.552	0.0	50	0.0	9.74	0.00
	Ceiling Losses	11.969	0.0	50	0.0	9.74	0.00
	Floor Losses	34.485	0.0	50	0.0	9.74	0.00
	Wall Losses	13.686	0.0	50	0.0	9.74	0.00
		103.648	0.0		0.0		0.00
Type B	Infiltration	27.101	460.7	50	921.4	9.74	8978.05
	Windows/Doors	11.291	191.9	50	383.9	9.74	1740.50
	Ceiling Losses	5.368	91.3	50	182.7	9.74	1780.37
	Floor Losses	8.088	137.5	50	275.1	9.74	2677.42
	Wall Losses	12.476	212.1	50	424.2	9.74	4133.09
		65.924	1120.7		2241.4		21839.43
Type C	Infiltration	20.389	1236.4	50	2476.7	9.74	24132.06
	Windows/Doors	11.343	551.5	50	1303.1	9.74	12696.61
	Ceiling Losses	5.973	352.4	50	704.8	9.74	6867.37
	Floor Losses	6.826	402.7	50	805.5	9.74	7848.09
	Wall Losses	12.515	738.4	50	1476.8	9.74	14389.01
		57.346	3381.4		6765.8		65933.17
Hot Water:	Households	24.624	1871.4	50	3742.8	9.74	36468.78
Cooking:	Households	4.320	328.3	65	505.1	15.83	7997.54
Lights/Appliances	Households	21.264	1692.1	32.2	5256.5	11.79	61788.48
TOTALS			8339.9		18421.8		194027.39
PER CAPITA ENERGY USE			28.3				646.76
PER HOUSEHOLD ENERGY USE			110.6				2552.99

WHAT'S THE DIFFERENCE BETWEEN THE ENERGY EFFICIENT HOME PROGRAMS?

ee energy efficient

super ee energy efficient

R-2000

SUPER ENERGY EFFICIENT HOME PROGRAM

"Double E" Certified Home

A "Double E" certified home is a new home built in accordance with the recommendations of the "Energy Efficient Program" and its minimum requirements concerning:

- -thermal insulation
- -air/vapour barrier
- -ventilation
- -windows and doors
- -heating systems and appliances
- -regulating devices
- -lighting, and
- -domestic water heater.

Program developed by the Canadian Electrical Association and sponsored by its member electric utilities.

"Super Double E" Home

A "Super Double E" home is a new home designed and built to an energy consumption budget that falls within the annual limit of 10,600 kWh for lighting, household appliances and hot water, in addition to a maximum space heating as listed below:

Typical Locality	Celsius Degree Days	Maximum Space Heating Energy Consumption ($kWh/m^2.y$)
Charlottetown, P.E.I.	4,623	40
Edmonton, Alta.	5,589	47
Fredericton, N.B.	4,699	40
Halifax, N.S.	4,123	36
Montreal, Que.	4,471	39
St. John's, Nfld.	4,804	41
Saskatoon, Sask.	6,027	50
Toronto, Ont.	4,082	36
Vancouver, B.C.	3,007	28
Winnipeg, Man.	5,889	49

Note: A "Super Double E" home must also meet the "Double E" minimum basic requirements.

Program developed by the Canadian Electrical Association and sponsored by its member electric utilities.

"R-2000" Home

An "R-2000" home is a home which is designed and built within the energy consumption budget set by the "Super Double E" home guidelines. Such a home is part of a demonstration program promoted by Energy, Mines and Resources Canada, through the Home Urban Development Association of Canada (HUDAC), with the support of the CEA.

1982 Pilot Project: 30 homes throughout Canada.

1983 Objective: 300 homes throughout Canada.

Program developed by Energy, Mines and Resources Canada and HUDAC, and supported by CEA.

Sponsored by Electric Utilities
as members of the Canadian Electrical Association

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